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### **EDITOR/BUSINESS MANAGER:**

**James H. Martin**

Dept. of Biology - PRC

J. Sargeant Reynolds Community College

P.O. Box 85622

Richmond, VA 23285-5622

Phone: (804)371-3064

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# Tidal Freshwater Ecosystems

## A Symposium Held at the Virginia Academy of Science Annual Meeting

May 25, 1990

George Mason University

Fairfax, VA 22030

R. Christian Jones, Organizer

Tidal freshwater ecosystems occur in virtually all of the drowned river valley estuary systems of the east coast of North America. Both morphometric and hydrologic factors are important in establishment of a tidal freshwater zone at the head of an estuary. Freshwater inflow must be sufficient to displace all brackish water from the area. Furthermore, the basin must be restricted enough to allow accumulation of the incoming freshwater to occur without immediate mixing with the brackish estuarine water. These conditions are met in many of the larger rivers draining the mid-Atlantic states including the Delaware, the Hudson, and Chesapeake Bay subestuaries such as the James and the Potomac. The Potomac has a zone of tidal freshwater stretching about 60 km from Chain Bridge to near Quantico which contains some 200-800 million cubic meters of water (Lippson et al. 1979. Environmental Atlas of the Potomac River Estuary. Johns Hopkins University Press). The range in volumes results from the seasonal variation in freshwater inflow resulting in a boundary with brackish water which varies seasonally.

The tidal freshwater zone shares many hydrologic characteristics with the estuary proper, but the biological and chemical characteristics are essentially those of an inland freshwater ecosystem. The tidal freshwater zone has been likened to a lake or reservoir in which the water sloshes back and forth with the tides (Jones et al., this volume). The fauna and flora of the tidal freshwater region bears much more resemblance to a nearby lake than the adjacent estuarine ecosystem. The exceptions to this rule are the nektonic organisms such as fish and crabs which may move into the tidal freshwater zone on a seasonal basis.

Given the tendency of large human communities to be established near the head of tide in large rivers it is understandable that tidal freshwater regions have been subjected to large volumes of treated and untreated waste. Wastewater treatment plant discharges into the tidal freshwater portion of the Potomac River constitute over 450 million gallons per day, a substantial portion of the total freshwater inflow. Historically, this proximity to large sources of municipal and industrial wastes has had severe impacts on tidal freshwater ecosystems. The tidal freshwater Potomac River was subjected to repeated algal blooms for many years attributable to discharge of domestic waste. The Kepone contamination of the James river originated from and heavily impacted the tidal freshwater zone of the James River. Clearly, freshwater ecosystems occur at a major locus of potential anthropogenic impact.



This symposium was organized to bring together individuals working on a variety of different organisms and in several different tidal freshwater systems. The idea was to promote communication among workers engaged in the same types of studies on geographically different tidal freshwater systems and also among workers engaged in different types of biota within the same system. Eighteen papers were presented by scientists from sixteen institutions located in four states. Studies encompassed aquatic macrophyte, phytoplankton, zooplankton, benthic invertebrate, and fish communities. Abstracts from all presentations were published in the Summer 1990 issue of the Virginia Journal of Science (Vol. 41, No. 2, pp. 85-89). Participants were invited to submit papers for a symposium proceedings. Following review, three papers resulting from the symposium were submitted for publication in the proceedings of the symposium. R. Christian Jones served as editor for all papers except that of Jones, Buchanan, and Andrele which was refereed by Donald P. Kelso.

These symposium proceedings are dedicated to the memory of Dr. William E. Odum, a pioneer in the study of tidal freshwater ecosystems.

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## Annual Variation in Biomass and Production of a Tidal Freshwater Wetland and Comparison with other Wetland Systems

Dennis F. Whigham, Smithsonian Environmental Research Center, Box 28, Edgewater, MD 21037 and

Robert L. Simpson, Office of the Provost, University of Michigan - Dearborn, Dearborn, MI 48128

### ABSTRACT

Tidal freshwater wetlands are characterized as being highly productive and having the productivity shared by a large number of perennial and annual species. In this paper, we report results from an 11 year study of net annual aboveground production for a high marsh community in a New Jersey tidal freshwater wetland. Between year patterns of production are examined for the dominant species and for the overall community. Results from the New Jersey study are compared to similar data from other types of wetlands. Tidal freshwater wetlands appear to be unique because they have a fairly low coefficient of variation (c. 20%) and a high diversity of dominant species. Reasons for this pattern are considered.

### INTRODUCTION

Most wetlands are highly productive yet there is almost nothing known about the range of variation in production that occurs from one year to the next (Good et al., 1978, Brinson et al., 1981, Mitsch and Gosselink, 1986). High levels of annual variation could have important implications as most of the net annual biomass production in wetlands enters either the detritus or grazing food chains and benefits secondary consumers. Whigham et al., (1989b), for example, found that net aboveground production of *Typha angustifolia* varied by as much as 75% in a brackish wetland. Working in the same wetland during the same time period, Jordan and Correll (1991) found significant yearly differences in the magnitude of nutrient import and/or export. How typical were those findings and what are their implications for wetland structure and function? Our objective is to consider the general question of how variable annual production is within and between different types of wetlands. We first consider annual variation in aboveground production for a tidal freshwater wetland in New Jersey and then compare those data with published data for other types of wetlands.

### STUDY SITE

The Hamilton Marshes are part of the complex of tidal freshwater wetlands that are common along the eastern coast of the U.S. (Odum et al., 1984). They are the northernmost tidal freshwater wetlands in the Delaware River system and have been the site of studies on vegetation (Leck et al., 1988; West and Whigham, 1976; Whigham and Simpson, 1977, 1982; Whigham et al., 1978), water quality (Simpson et al., 1981, 1983a, 1983b), seed bank dynamics (Leck and Graveline, 1979; Leck and Simpson, 1987a and 1987b; Leck et al., 1989; Parker and Leck, 1985), decom-

position (Whigham et al., 1989a), and wastewater management (Whigham and Simpson, 1976 and 1978; Simpson et al., 1983a).

In this paper, we describe results for six years of an eleven year period at one of the sites that was initially sampled in 1973 (Whigham and Simpson, 1975). The site is a high marsh habitat (Simpson et al., 1983a) that is normally flooded for two to three hours during each tidal cycle. The high marsh, typically the most diverse vegetation zone in tidal freshwater wetlands (Odum et al., 1984; Simpson et al., 1983a), has a heterogeneous mixture of annual and perennial species. The most abundant species are: Perennials - *Acorus calamus* (Sweet flag), *Peltandra virginica* (Arrow arum), *Typha latifolia* (Common cattail), *Sagittaria latifolia* (Arrowhead); Annuals - *Polygonum arifolium* (Halberd tearthumb), *Polygonum sagittatum* (Tearthumb), *Zizania aquatica* var. *aquatica* (Wild rice), *Bidens laevis* (Bur marigold), and *Impatiens capensis* (Touch-me-not).

Vegetation was sampled throughout the growing seasons of 1973-1977 and 1985. All sampling took place within an area of approximately 100 x 100 m and all aboveground biomass in seven randomly located quadrats was harvested on each sampling date. The samples were washed to remove sediment, sorted by species, and dried to constant weight. Standing crop biomass for each sampling date was summed for annuals, perennials, and all species combined. Because the species reach peak biomass at different times, net annual aboveground biomass production was estimated as the sum of the peak biomass for each species (see Whigham et al., 1978 for a detailed description of the method).

For the literature comparison, we used data from studies of three or more years in duration. Peak aboveground biomass or estimates of annual production were averaged and the coefficient of variation (C.V.) calculated to compare the amount of variation in populations having different means (Sokal and Rohlf, 1969).

## RESULTS AND DISCUSSION

Seasonal biomass patterns were similar for all years. Perennial biomass (Fig. 1) was highest early in the growing season and decreased with time. The pattern for all years was similar except for 1973 when perennial biomass was lower because *Typha* was not present in any of the sampled quadrats. In contrast, biomass of annuals (Fig. 1) increased throughout the growing season and the yearly patterns were very similar. The annual:perennial biomass ratio (Fig. 2) showed the seasonal shift in dominance from perennials to annuals and demonstrated that (except in 1973 when there was not any *Typha* in the harvested samples) the ratio changes little from year-to-year.

Net annual aboveground production ranged from approximately 1500 to 2000 g/m<sup>2</sup> for all years except 1975 (Fig. 3) when the production estimate was higher due to the presence of *Typha latifolia* for the first time (Fig. 4) and higher biomass for *Acorus calamus* (Fig. 4) and *Bidens laevis* (Fig. 5). Annual aboveground production of perennials varied widely between years for all species except *Peltandra virginica* which was also the most productive perennial species (Fig. 4). Net annual production of the dominant annuals (Fig. 5) was also quite variable for all species due to highly variable spatial patterns of distribution. The data also give some indication of successional processes. *Bidens laevis* was completely absent from the site in 1985

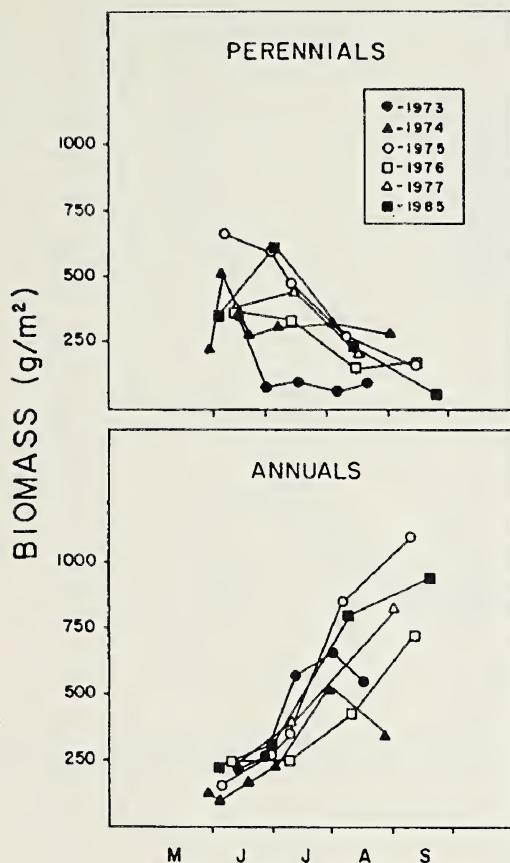


FIGURE 1. Seasonal biomass patterns for perennials and annuals in the Hamilton Marshes.

(Fig. 5) but the loss of *Bidens* was compensated for by a large increase in the biomass production of *Impatiens capensis* (Fig. 5).

There was clearly a high level of interspecific variation in annual biomass production (Figs. 4 and 5) but inter-annual differences in biomass and production were fairly small at the community level (Fig. 3) even though the presence and abundance of some species changed from 1973 to 1985. For the six years, the C.V. of net annual aboveground production was 22.8% which is fairly low considering the large number of dominant species that occur in tidal freshwater wetlands.

Table 1 is a summary of annual biomass and production data for a range of wetland types. The highest C.V.'s appear to be associated with brackish intertidal wetlands that experience large fluctuations in salinity. The C.V. for a regularly flooded *Typha angustifolia* dominated wetland in Maryland was 75% and the variation was associated with high inter-annual variation in salinity during the early part of the growing season (Whigham et al., 1989b). The C.V.'s were also high for three vegetation types in an irregularly flooded high marsh wetland (Drake et al., 1989) that is within 0.5 km of the *Typha* dominated low marsh studied by Whigham et al. (1989b). The C.V. of the high marsh ranged from 15.3 for areas dominated by *Scirpus olneyi* to 55.6 in areas dominated by *Spartina patens*. Areas dominated by *Distichlis spicata* had a C.V. of 44.3 and the mean for all three vegetation types,

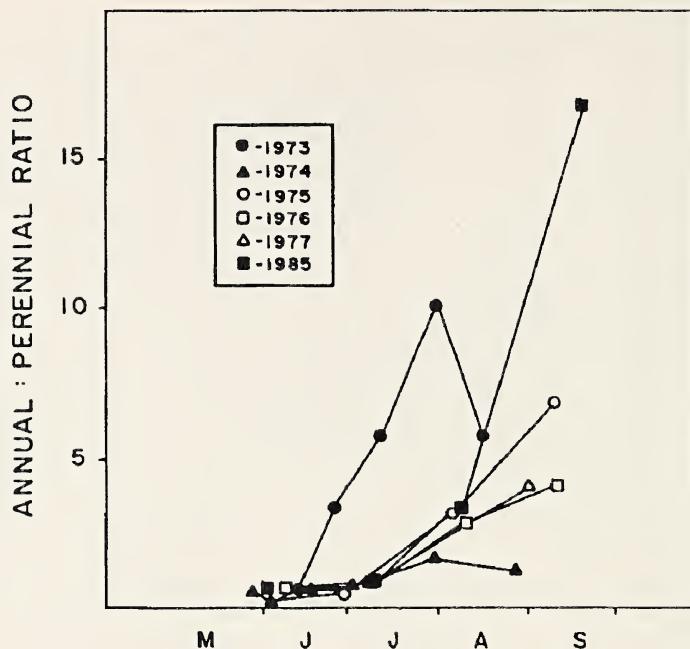


FIGURE 2. Ratios of annual:perennial biomass.

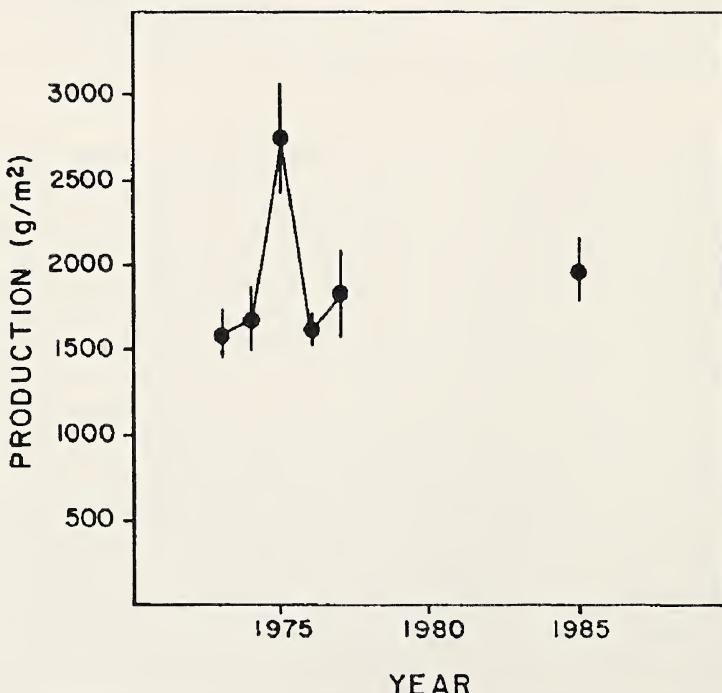


FIGURE 3. Annual net aboveground biomass production for the High Marsh habitat in the Hamilton Marshes. Values are means  $\pm$  1 standard error.

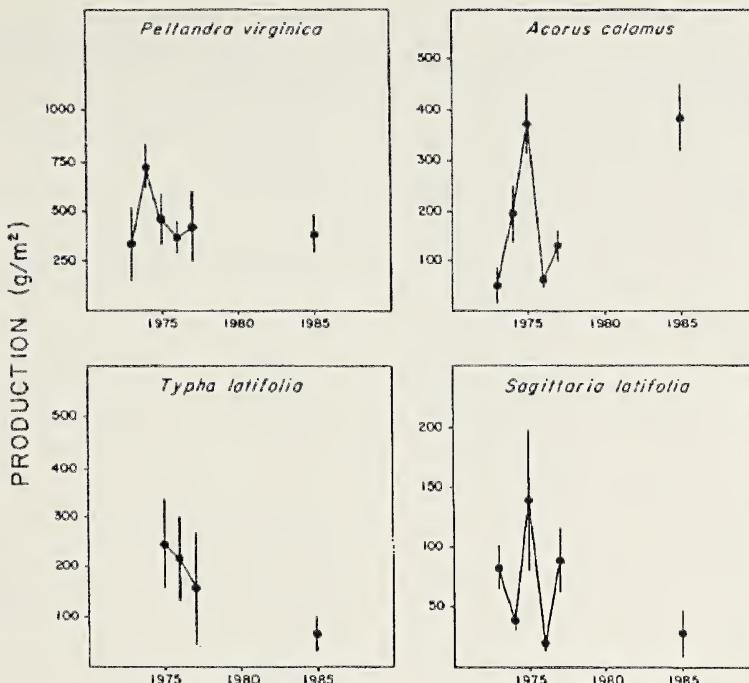


FIGURE 4. Annual net aboveground biomass production for the four dominant perennial species in the High Marsh habitat in the Hamilton Marshes. Values are means  $\pm$  1 standard error.

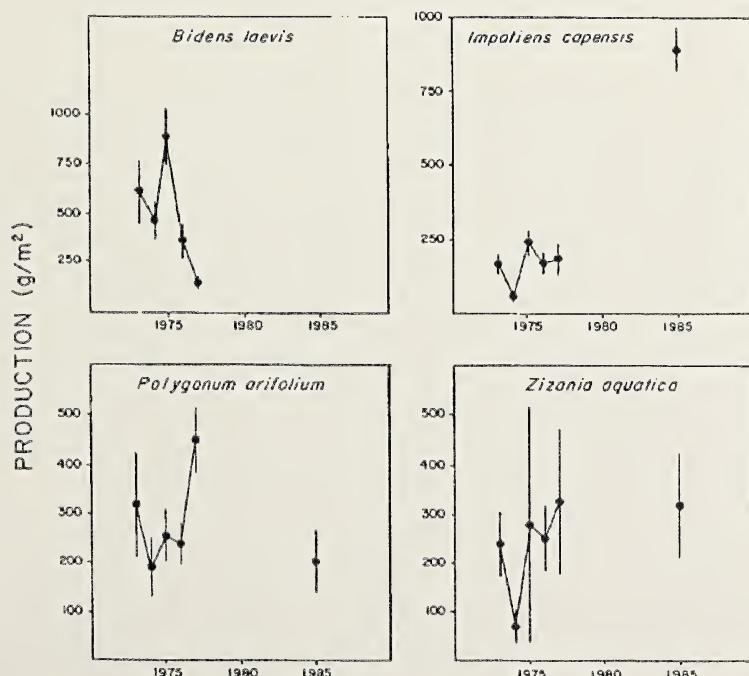


FIGURE 5. Annual net aboveground biomass production for the four dominant annual species in the High Marsh habitat in the Hamilton Marshes. Values are means  $\pm$  1 standard error.

all located within a few meters of each other, was 43.4. The high C.V.'s for the vegetation studied by Drake et al. (1989) was most likely due to seasonal differences in precipitation which influenced interstitial salinity. *Scirpus* areas are topographically lower and are flooded more regularly and have less variation in soil salinity than topographically higher areas dominated by *Spartina*.

The range in C.V. for annual biomass production appears to be somewhat less in coastal saltmarsh wetlands (Table 1). Zedler et al., (1980) conducted a three year study of a California hypersaline wetland dominated by *Spartina foliosa*. They sampled along a flooding gradient and found that the C.V. was least in the low marsh (9.2) and highest in the high marsh (21.4). The higher C.V. in the high marsh was most likely caused by large changes in soil salinity in the high marsh habitat that floods infrequently. The reverse pattern was found by Dame and Kenny (1986) for a *Spartina alterniflora* dominated wetland in the North Inlet estuary in South Carolina (Table 1). Dame and Kenny found that the C.V. was least in the high marsh (2.2) and greatest in the low marsh (20.9). They believed that higher variability in the low marsh was due to changes in freshwater input to the estuary. Over a thirteen year period, Teal (1986) found a C.V. of 9.1 in a *Spartina alterniflora* dominated wetland in Massachusetts. One wetland that had a high C.V. (Range = 31-62; Mean = 46.5) was a managed (mowed) and infrequently flooded saltmarsh in The Netherlands (de Leeuw et al., 1990). The high annual variation in that system was caused by year-to-year variation in soil conditions (soil salinity and soil moisture content).

Five data sets (Table 1) indicate that the C.V. can be expected to range between 15 and 40% for non-tidal freshwater wetlands. In a Swedish *Carex rostrata* dominated wetland with regulated water levels, the C.V. was 16.1 for a three year period (Hultgren, 1989). Over a five year period, Solander (1983) found that the C.V. in a Swedish wetland dominated by *Carex rostrata* and *Equisetum fluviatile* was 21.2 in areas that were fertilized and 34.9 in unfertilized areas. Koerselman et al. (1990) found only small differences in the C.V. for groundwater discharge (30.7) and groundwater recharge (31.5) fens in The Netherlands. Both fens were mowed yearly during the growing season and they were surrounded by heavily fertilized pastures. Kadlec and Bevis (1990) conducted a five year study of a Michigan bog that received sewage wastewater. The bog had been undergoing dramatic vegetation changes from an oligotrophic *Picea-Carex-Chamaedaphne* dominated bog to one dominated by *Typha latifolia*. The C.V. for areas dominated by *Typha* ranged from 6.9 at c. 900 m from the point of wastewater discharge to 40.9 at c. 2500 m. This suggests that conversion to a more eutrophic condition near the point of discharge provided a steady supply of water and nutrients that resulted in a decrease in the variation in annual production. In the only wetland with clear seasonality in hydrologic conditions, Rogers and Breen (1990) measured a C.V. of 31.6 over a four year period in a floodplain wetland in South Africa.

Table 1 indicates that most wetlands have a low dominance diversity and that there is a wide range of C.V.'s. Saltmarshes that experience few changes in salinity have the lowest C.V.'s and brackish tidal wetlands which experience wide fluctuations in salinity conditions have the highest C.V.'s. Tidal freshwater wetlands are in the middle of the range for freshwater wetlands but they are unique because they have a high species diversity and fairly low C.V.. The two Dutch systems with levels

TABLE 1. Comparison of coefficients of variation for different wetlands. Species refers to the number of dominant species cited by the authors.

Source	Wetland Type	Habitat	Species	Study Years	C.V.
Zedler et al., 1980	Saltmarsh	Low Marsh	1	3	9.2
		Intermediate	2	3	11.7
		High Marsh	2	3	21.4
Dame and Kenny, 1986	Saltmarsh	Low Marsh	1	4	20.9
		Intermediate	1	4	5.7
		High Marsh	1	4	2.2
de Leeuw et al., 1990	Saltmarsh	High Marsh	8	13	46.5
Teal, 1986	Saltmarsh	High Marsh	1	13	9.1
Drake et al., 1989	Brackish	High Marsh	1	4	15.3
		High Marsh	1	4	55.6
		High Marsh	1	4	44.3
Whigham et al., 1989	Brackish	Low Marsh	1	6	75.0
This study	Tidal Fresh	High Marsh	8	6	22.8
Hultgren, 1989	Freshwater	Lacustrine	1	3	16.1
Solander, 1983	Freshwater	Lacustrine	2	5	21.2
		Lacustrine	2	5	34.9
Koerselman et al., 1990	Freshwater	Fen	7	3	30.7
		Fen	7	3	31.5
Kadlec and Bevis, 1990	Freshwater	Bog	1	4	6.9
		Bog	1	4	40.9
Rogers and Breen, 1990	Freshwater	Floodplain	1	4	31.6

of diversity similar to the Hamilton Marshes and somewhat higher C.V.'s, were both managed (mowed) and received high levels of nutrient inputs.

We believe that there are three reasons why tidal freshwater wetlands have a high species diversity and low C.V.. First, the energy signature (ie., tidal flooding) is predictable and high marsh habitats are flooded for 2-3 hours during each tidal cycle. Regular tidal inundation and flushing transports sediments and nutrients to the wetland while flushing oxidizes the surface layer of the substrate and removes salts, and potential harmful chemicals that could have a negative affect on production. Second, nutrient levels are high in most tidal freshwater wetlands because they are located in the upper reaches of estuaries where nutrient levels are high due to agricultural runoff and/or wastewater effluent (Simpson et al., 1983a). High nutrient levels assure that annual primary production will be high each year. Third, the high diversity and dominance of annual species is unique among estuarine wetlands (Odum et al., 1984). This feature of tidal freshwater wetlands allows for species compensation so that annual production levels remain high and fairly constant even though there may be shifts in the distribution and abundance of species from one year to the next. Finally, data from the Hamilton Marshes and the data summarized in Table 1 suggest that the high species diversity of tidal freshwater wetlands enables them to be buffered against changing environmental

conditions. This situation contrasts sharply with brackish tidal wetlands which experience wide ranges in production (Whigham et al., 1989) and pronounced changes in species diversity. The universality of these findings, however, and their implications for ecosystem structure and function await additional long-term studies.

#### ACKNOWLEDGMENTS

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#### LITERATURE CITED

- Brinson, M. M., A. E. Lugo, and S. Brown. 1981. Primary Productivity, Decomposition and Consumer Activity in Freshwater Wetlands. *Ann. Rev. Ecol. Syst.* 12: 123-161.
- de Leeuw, J., H. Olff, and J. P. Bakker. 1990. Year-to-Year Variation in Peak Above-ground Biomass of Six Salt-marsh Angiosperm Communities as Related to Rainfall Deficit and Inundation Frequency. *Aq. Bot.* 36: 139-152.
- Dame, R. F. and P. D. Kenny. 1986. Variability of *Spartina alterniflora* Primary Production in the Euhaline North Inlet Estuary. *Mar. Ecol. Prog. Ser.* 32: 71-80.
- Drake, B. G., S. J. Arp, L. Balduman, P. S. Curtis, J. Johnson, D. Kabara, P. W. Leadley, W. T. Pockman, D. Seliskar, M. L. Sutton, D. Whigham, and L. Ziska. 1989. Response of Vegetation to Carbon Dioxide. 051 Effects of Elevated Carbon Dioxide on Chesapeake Bay Wetlands. IV. Ecosystem and Whole Plant Responses. April-November 1988. U.S. Department of Energy, Carbon Dioxide Research Division. Office of Energy Research, Washington, D.C. 20545. 105 pp.
- Good, R. E., D. F. Whigham, and R. L. Simpson, eds. 1978. Freshwater Wetlands: Ecological Processes and Management Potential. Academic Press. New York. 378 pp.
- Hultgren, A. B. C. 1989. Above-ground Biomass Variation in *Carex rostrata* Stokes in two Contrasting Habitats in Central Sweden. *Aq. Bot.* 34: 341-352.
- Jordan, T. E. and D. L. Correll. 1991. Continuous Automated Sampling of Tidal Exchanges of Nutrients by Brackish Marshes. *Est. Coast. Shelf Sci.* 32:527-545.
- Kadlec, R. H. and F. B. Bevis. 1990. Wetlands and Wastewater: Kinross, Michigan. *Wetlands* 10: 77-92.
- Koerselman, W., S. A. Bakker, and M. Blom. 1990. Nitrogen, Phosphorus, and Potassium Mass Balances for Two Small Fens Surrounded by Heavily Fertilized Pastures. *J. Ecol.* 78: 428-442.
- Leck, M. A. 1989. Wetland Seed banks. In *Ecology of Soil Seed Banks* (M. A. Leck, V. T. Parker, and R. L. Simpson, eds). pp. 283-304. Academic Press, New York, NY.
- Leck, M. A. and K. J. Graveline. 1979. The Seed Bank of a Freshwater Tidal Marsh. *Am. J. Bot.* 66: 1006-1015.
- Leck, M. A. and R. L. Simpson. 1987a. Seed Bank of a Freshwater Tidal Wetland: Turnover and Relationship to Vegetation Change. *Am. J. Bot.* 74: 360-370.

- Leck, M. A. and R. L. Simpson. 1987b. Spore Bank of a Delaware River Freshwater Tidal Wetland. Bull. Torrey Bot. Club 114: 1-7.
- Leck, M. A., R. L. Simpson, D. F. Whigham, and C. F. Leck. 1988. Plants of the Hamilton Marshes: A Delaware River freshwater tidal wetland. Bartonia 54: 1-17.
- Leck, M. A., R. L. Simpson, and V. T. Parker. 1989. The Seed Bank of a Freshwater Tidal Wetland and its Relationship to Vegetation Dynamics. In Freshwater Wetlands and Wildlife (R. R. Sharitz and J. W. Gibbons, eds.). CONF-8603101. DOE Symposium Series No. 61. USDOE Office of Sci. and Tech. Inf., Oak Ridge, TN.
- Mitsch, W. J. and J. G. Gosselink. 1986. Wetlands. Van Nostrand-Reinhold, New York, NY. 537 pp.
- Odum, W. E., T. J. Smith, III, J. K. Hoover, and C. C. McIvor. 1984. The Ecology of Tidal Freshwater Marshes of the United States East Coast: A Community Profile. FWS/OBS-83/17. U.S. Fish and Wildlife Service, Slidell, LA. 177 pp.
- Parker, V. T. and M. A. Leck. 1985. Relationships of Seed Banks to Plant Distribution Patterns in a Freshwater Tidal Wetland. Am. J. Bot. 72: 161-174.
- Rogers, K. H. and C. M. Breen. 1990. Waterfowl of a Subtropical African Floodplain. I. Seasonality of Community Composition and Food Resources. Wet. Ecol. Mgt. 1: 85-98.
- Simpson, R. L., R. E. Good, R. Walker, and B. R. Frasco. 1981. Dynamics of Nitrogen, Phosphorus, and Heavy Metals in Delaware River Freshwater Tidal Wetlands. Center for Coastal and Environmental Studies. Rutgers Univ., New Brunswick, NJ. 192 pp.
- Simpson, R. L., R. E. Good, M. A. Leck, and D. F. Whigham. 1983a. The Ecology of Freshwater Tidal Wetlands. Bioscience 34: 255-259.
- Simpson, R. L., R. E. Good, B. J. Dubinski, J. J. Pasquale, and K. R. Philipp. 1983b. Fluxes of Heavy Metals in Delaware River Freshwater Tidal Wetlands. Center for Coastal and Environmental Studies. Rutgers Univ., New Brunswick, NJ. 78 pp.
- Sokol, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Company, San Francisco, CA. 776 pp.
- Solander, D. 1983. Biomass and Shoot Production of *Carex rostrata* and *Equisetum fluviatile* in unfertilized and fertilized subarctic lakes. Aq. Bot. 15: 349-366.
- Teal, J. M. 1986. the Ecology of Regularly Flooded Salt Marshes of New England: A Community Profile. FWS/OBS-85/7.4. U. S. Fish and Wildlife Service, Slidell, LA. 61 pp.
- West, D. and D. F. Whigham. 1976. Seed Germination of Arrow Arum (*Peltandra virginica* L.). Bartonia 44:44-49.
- Whigham, D. F. and R. L. Simpson. 1975. Ecological Studies of the Hamilton Marshes. Progress Report for the Period June, 1984-January, 1975. Biology Department. Rider College, Lawrenceville, NJ. 185 pp.
- Whigham, D. F. and R. L. Simpson. 1976. the Potential Use of Freshwater Tidal Marshes in the Management of Water Quality in the Delaware River. In Biological Control of Water Pollution (J. Toubier and R. W. Pierson, Jr., eds.). pp. 173-186. Univ. Penn. Press. Philadelphia, PA.

- Whigham, D. F. and R. L. Simpson. 1977. Growth, Mortality, and Biomass Partitioning in Freshwater Tidal Wetland Populations of Wild Rice (*Zizania aquatica* var. *aquatica*). Bull. Torrey Bot. Club 104: 347-351.
- Whigham, D. F. and R. L. Simpson. 1978. Nitrogen and Phosphorus Movement in a Freshwater Tidal Wetland Receiving Sewage Effluent. In Coastal Zone 78: Symposium on Technical, Environmental, Socioeconomic and Regulatory Aspects of Coastal Zone Management. pp. 2189-2203. Am. Soc. Civil Eng., San Francisco, CA.
- Whigham, D. F. and R. L. Simpson. 1982. Germination and Dormancy Studies of *Pontederia cordata* L. Bull. Torrey Bot. Club 109: 524-528.
- Whigham, D. F., J. McCormick, R. E. Good, and R. L. Simpson. 1978. Biomass and Primary Production in Freshwater Tidal Wetlands of the Middle Atlantic Coast. In Freshwater Wetlands: Ecological Processes and Management Potential (R. E. Good, D. F. Whigham, and R. L. Simpson, eds.). pp. 3-20. Academic Press, New York, NY.
- Whigham, D. F., R. L. Simpson, R. E. Good, and F. A. Sickels. 1989a. Decomposition and Nutrient-Metal Dynamics of Litter in Freshwater Tidal Wetlands. In Freshwater Wetlands and Wildlife (R. R. Sharitz and J. W. Gibbons, eds.). pp. 167-188. CONF-8603101, DOE Symp. Series. No. 61. USDOE Office of Sci. and Tech. Inf., Oak Ridge, TN.
- Whigham, D. F., T. E. Jordan, and J. Miklas. 1989b. Biomass and Resource Allocation of *Typha angustifolia* L. (Typhaceae): The Effect of Within and Between Year Variation in Salinity. Bull. Torrey Bot. Club 116: 364-370.
- Zedler, J. B., T. Winfield, and P. Williams. 1980. Salt Marsh Productivity with Natural and Altered Tidal Circulation. Oecologia 44: 236-240.

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## Seasonal Phytoplankton Development Within Three Rivers In The Lower Chesapeake Bay Region.

Harold G. Marshall and Lewis F. Affronti

Department of Biological Sciences

Old Dominion University

Norfolk, Virginia 23529-0266

### ABSTRACT

The seasonal and inter-annual concentrations of phytoplankton were studied over a 50 month period in the lower James, York and Rappahannock Rivers. Differences in the onset, duration and magnitude of major seasonal growth periods varied from year to year. There was a tendency for spring, summer and fall maxima, with a winter period of reduced abundance. An additional study of picoplankton over a 12 month period indicated greatest abundance during summer and fall, with least development in winter.

### INTRODUCTION

Schubel and Pritchard (1987) described the James, York and Rappahannock Rivers as three major tributaries of the Chesapeake Bay, collectively responsible for 18.6% of its total annual stream flow. In these three rivers, Anderson (1986) noted phytoplankton maxima occurred in areas of tidal freshwater. Filardo and Dunstan (1985) reported an inverse relationship between phytoplankton abundance in the upper oligohaline reach of the James River and the biomass in the mesohaline sections. They related the nutrient dynamics of the oligohaline region of the James with nutrient levels and the onset of the spring bloom downstream. Marshall and Alden (1990a) identified phytoplankton differences in seasonal and site assemblages in the James, York and Rappahannock Rivers. They reported decreasing concentrations downstream in these rivers and that spatial (site) effects are responsible for the majority of the explained variance (58%) among the floral assemblages. Major temporal influences included the onset and duration of the spring rains. Further associations between specific nutrient concentrations and growth of different assemblages in freshwater and marine habitats were presented by Hecky and Kilham (1988), and in the Chesapeake Bay by McCarthy et al. (1977) and Sellner (1987), among others. Phytoplankton assemblages in the lower Chesapeake Bay were discussed by Marshall and Lacouture (1986), who reported these populations were dominated by neritic diatoms, dinoflagellates, cryptomonads and a cyanobacteria picoplankton component.

Marshall and Alden (1990a) described the initial results of a phytoplankton monitoring program of the lower James, York and Rappahannock Rivers. By applying a series of discriminant and multivariate analysis procedures to a 16 month data set, they identified 3 station (spatial) groups and 5 seasonal assemblages within these rivers. Seasonal and spatial phytoplankton assemblages were also identified in the lower Chesapeake Bay by Marshall and Alden (1990b). This paper will focus on the composite phytoplankton concentrations within these three station groups presented by Marshall and Alden (1990a) to identify year to year fluctuations in abundance. The objectives of this report include 1) the comparison of the annual

composition and cycles in phytoplankton abundance at sites within the lower James, York and Rappahannock Rivers over a four year period, and 2) the identification of year to year variation in the phytoplankton abundance during this period.

### METHODS

This report is based on a 50 month study between March 1986 and April 1990. Monthly collections were taken from two stations in the James and Rappahannock Rivers and one station in both the York River and Pamunkey River, which is a tributary to the York River (Figure 1). At each station, a 15 liter composite water sample was taken by water pump and hose at five depths from just above the pycnocline to the surface. From this composite a 500 ml sub-sample was preserved with Lugols solution. A similar procedure was followed for waters below the pycnocline to a near bottom depth. Sites lacking a pycnocline were sampled in the upper and lower third of the water column. After 48 hours these sub-samples were processed through a series (3) of siphoning and settling procedures to obtain a 20-25 ml concentrate that was placed in a settling chamber and analyzed with an inverted plankton microscope. Cell counts were made at 315X and 500X with a minimum count and random field approach to produce an 85% accuracy estimate for cell concentrations (Venrick, 1978). These cell counts do not include the picoplankton. Analysis of this component was added in 1988 when counts of the picoplankton autotrophic cells were based on another sub-sample taken from the composite water sample and prepared for epifluorescent microscopy according to methods given by Porter and Feig (1980) and Waterbury et al. (1986). The mean monthly phytoplankton concentrations, for stations within each site group, were used in depicting the computer generated annual abundance patterns using Harvard Graphics.

### RESULTS

#### Phytoplankton Composition

Marshall and Alden (1990a) originally identified three groups of phytoplankton assemblages associated with station sites in these rivers. The three site groups were designated according to common salinity ranges for these areas as I. Tidal Fresh (station TF 5.5 in the James River), II. Oligo-mesohaline (station RET 5.2 in the James, TF 3.3 in the Rappahannock, and the York station RET 4.1), and III. Mesohaline (station RET 4.3 and RET 3.1 from the York and Rappahannock). Over the 16 month study period the James River Group I station (TF 5.5) was characterized by fresh water flora dominated by chlorophytes, diatoms and cyanobacteria. The major diatoms included *Skeletonema potamos*, *Melosira (Aulacoseira) granulata*, *Melosira (Aulacoseira) distans*, *Cyclotella striata* and a variety of benthic species. Peak concentrations were associated with late winter-early spring (February-April) and late summer-early fall (August-October). The chlorophytes consisted of a diverse group of unicellular and colonial forms such as *Scenedesmus quadricauda*, *Scenedesmus dimorphus*, *Chlorella* sp., *Ankistrodesmus falcatus*, *Pandorina* spp., *Tetrastrum* spp., and *Crucigenia tetrapedia*, among others. Although common year round, they generally had major growth periods in early spring and summer. Filamentous chlorophytes were rare and associated with entry from shoreline vegetation. In contrast, two cyanophyte groups were present

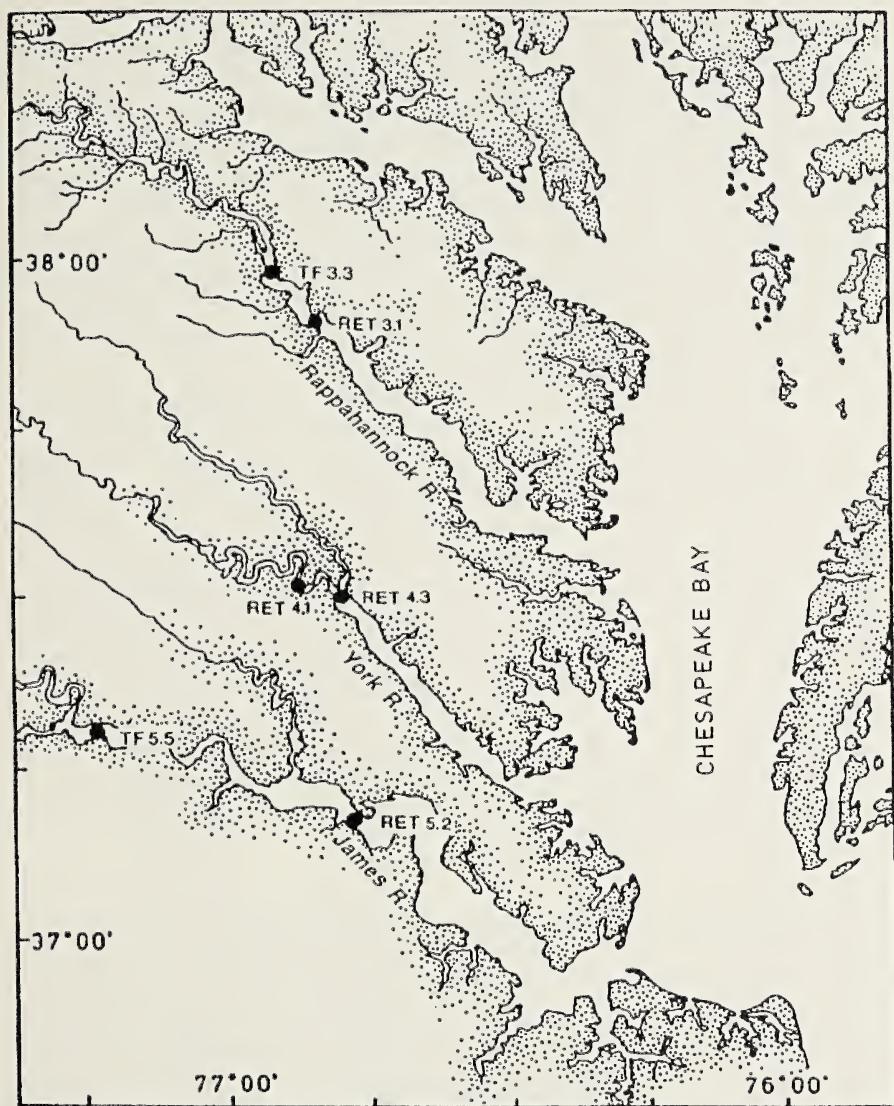


FIGURE 1. Station locations in the James, York and Rappahannock Rivers.

in all the collections. One was the ubiquitous picoplankton component (0.2 -2.0 microns) that included cyanobacteria of mainly *Synechococcus* spp. These cells had a major summer-early fall growth ( $10^9$  -  $10^{10}$  cells/L) with a seasonal low in winter. The other cyanobacteria groups were composed of mainly unicellular or colonial forms. These included *Microcystis aeruginosa*, *Microcystis incerta*, *Merismopedia tenuissima* and *Chroococcus limneticus*. Filamentous genera (e.g. *Nostoc*, *Anabaena*) were also common, but not abundant. The cyanobacteria were most numerous during summer and early fall. In addition to these categories, there was representation by cryptomonads, euglenoids, dinoflagellates and a mixed category of micro-flagellates.

The oligo-mesohaline Group II stations represented a transition to a mixed assemblage of fresh water and estuarine flora. The representation common to the lower Chesapeake Bay included the diatoms *Skeletonema costatum*, *Leptocylindrus minimus*, *Cyclotella caspia*, and numbers of others. Cryptomonads and dinoflagellates were also greater in numbers down stream, with concentrations of chlorophytes and cyanobacteria decreasing. The estuarine species were noted throughout the year in the more saline sub-pycnocline waters, which were associated with the transport of these species upstream. In contrast, higher concentrations of the tidal freshwater diatoms, chlorophytes and cyanobacteria were found above the pycnocline (moving downstream), than below the pycnocline. A variety of other neritic species were also found in the sub-pycnocline waters (e.g. *Chaetoceros* spp. silicoflagellates, among others).

In contrast, the mesohaline Group III stations were dominated by estuarine and neritic species. Common freshwater forms in the tidal fresh or oligo-mesohaline stations were replaced by species associated with more saline waters. For instance, *Skeletonema potamos*, *Cyclotella striata*, *Cyclotella* sp. and several *Melosira* (*Aulacoseira*) spp. were replaced by *Skeletonema costatum*, *Cyclotella caspia*, *Asterionella glacialis* and *Leptocylindrus minimus*. Dinoflagellates, cryptomonads and euglenoids also became more abundant. Among the dinoflagellates, a common species was *Katodinium rotundatum*, with *Prorocentrum minimum* and *Heterocapsa triquetra* having highest concentrations in the downstream reach of the rivers and in waters below the pycnocline. The cyanobacteria and chlorophytes decreased in abundance downstream, but *Microcystis* spp. and *Merismopedia* spp. were still common, specially during late summer and early fall. There were no major algal blooms observed during the collection period. However, between collection dates, several small and very localized dinoflagellate blooms were noted in mesohaline regions of these rivers (Marshall, 1989).

#### Phytoplankton Abundance

##### I. Tidal Fresh Water

Over the four year period, peaks ( $10^7$  -  $10^8$  cells/L) in phytoplankton abundance above the pycnocline occurred between spring (April) and fall (October), with lowest concentrations in winter (Figure 2-I). There was a modest increase in the 1986 spring-summer development followed by a slight decline in late summer and a fall peak in October. There were no major spring pulses in 1987 and 1988, but a major summer peak occurred in 1987 followed by a modest development in fall before the winter decline. In 1988, the fall abundance was larger than in summer. In contrast, there were major spring (April) maxima in 1989 and an early spring growth beginning in January 1990, and only modest summer and fall growth in 1989. Concentrations in the waters below the pycnocline generally mimicked the surface waters in composition and abundance, often exceeding them in concentrations (e.g. spring 1986, fall 1988), but were usually less abundant. Species mainly responsible for the peaks in spring and fall were diatoms and chlorophytes, while diatoms, cyanophytes, and chlorophytes were abundant in summer.

##### II. Oligo-mesohaline

In 1986, the phytoplankton concentrations above the pycnocline developed a modest spring (April) pulse ( $10^7$  cells/L) followed by another pulse in summer

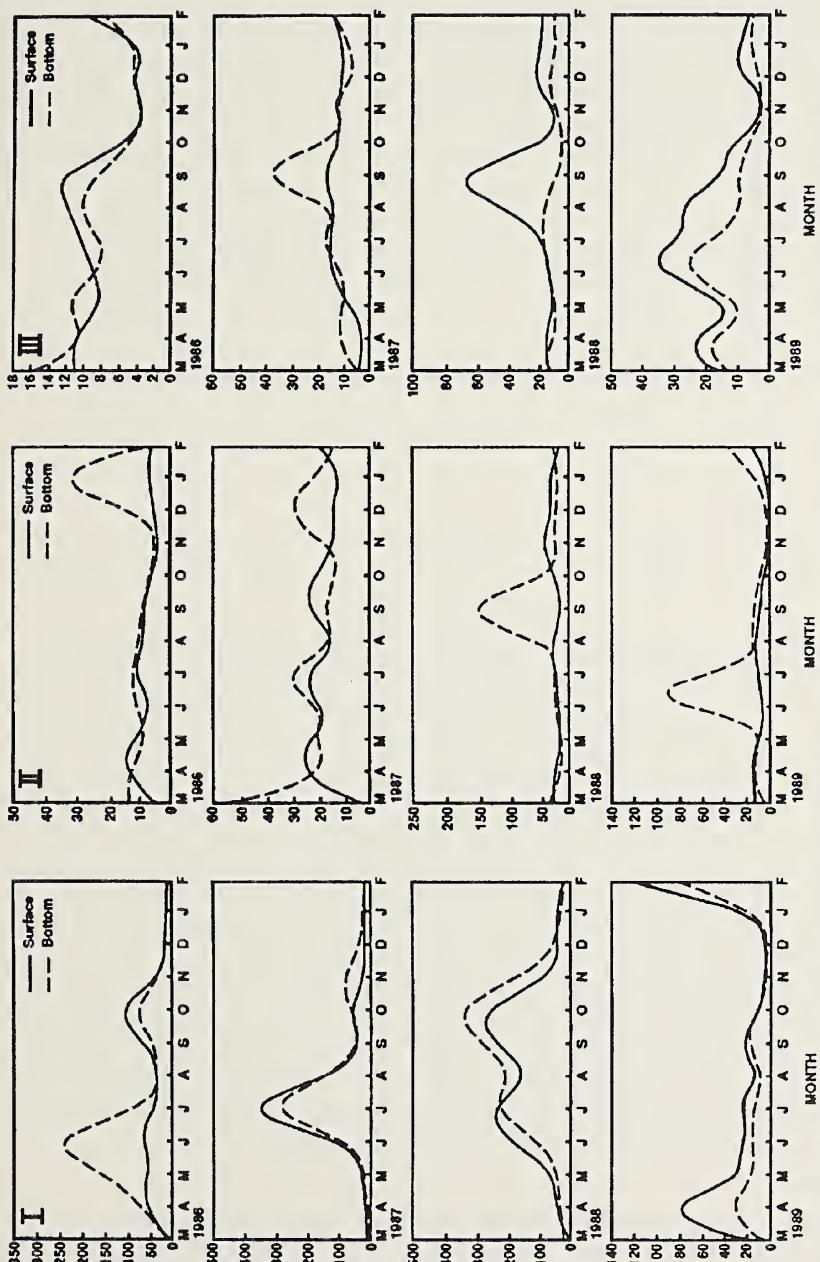


FIGURE 2. Mean monthly concentrations of phytoplankton above and below the pycnocline for all stations within each site group between 1986 and 1989 (Site Group I includes station TF 5.5, Site Group II stations TF 3.3, RET 4.1, RET 5.2 and Site Group III contains stations RET 3.1 and RET 4.3). Values are in number of cells/ $1 \times 10^6$ .

(July), before decreasing into winter, when another increase took place in January. There were modest peaks ( $10^7$  cells/L) in 1987 during spring (April), summer (July), and fall (September), before declining in winter. Another early spring development began in January, leading to modest pulses ( $10^7$  cells/L) in 1988 during spring, summer and fall. In 1989, a spring (April) pulse and an extended summer development occurred before declining into winter. Concentrations below the pycnocline in general followed this pattern, but there were occasions where cell abundance was greater below the pycnocline, e.g. winter (1986, 1987); summer (1987, 1989), and in fall (1988). During these periods, the populations below the pycnocline were usually dominated in abundance by diatoms. There were also distinct differences in the composition of the assemblages above and below the pycnocline during the collections. The floral composition below the pycnocline was mainly composed of neritic and estuarine species common to the Bay, compared to a tidal freshwater-estuarine mixture in the upper strata. These sites had a pattern of spring, summer and fall peaks that were mainly the product of diatoms, dinoflagellates, chlorophyceans and cyanobacteria, which reached concentrations of  $10^7$  to  $10^8$  cells/L. Abundance levels were generally higher at the James River Station (RET 5.2) compared to oligo and mesohaline stations in the other two rivers.

### III. Mesohaline

The largest concentrations of phytoplankton above the pycnocline for 1986 occurred in spring (April) and summer (August) and were at mean values of  $10^7$  cells/L. These values were followed by winter lows of  $10^6$  cells/L. In 1987, cell concentrations were generally low, with a modest increase in cell abundance over the summer to a fall maxima ( $10^7$  cells/L), that remained fairly constant into winter. During 1988, a modest spring development was followed by a maximum of  $10^7$  cells/L in fall (September), then a smaller pulse in winter (December). The abundance pattern in 1989 had several distinct maxima ( $10^7$  cells/L). These occurred in spring (March), summer (June) and winter (December). The winter-spring and late fall assemblages were dominated by diatoms, with diatoms, dinoflagellates, cyanobacteria, cryptomonads and euglenoids common dominants during summer and early fall. Many of the same species were abundant above and below the pycnocline, with a tendency for greater concentrations of diatoms below the pycnocline, but more phytoplankton above the pycnocline. The abundance of cells were generally less below the pycnocline, but seasonal maxima also occurred at these lower depths during spring, summer and fall. The dominant species at these stations were consistently estuarine and neritic species common to the Chesapeake Bay (Marshall and Lacouture, 1986). The freshwater cyanobacteria, chlorophyceans and diatoms were present, but in low concentrations and more common in the surface waters than below the pycnocline.

### Picoplankton

Concentrations of autotrophic cells over a 12 month period at station TF 5.5 in the James River are given in Figure 3. In addition to the phytoplankton cells described above the picoplankton represent a major autotrophic component of the local estuaries (Ray et al., 1989). Cell abundance was greatest during summer (June) followed by another pulse in fall ( $10^8$  to  $10^9$  cells/L), with lowest concentra-

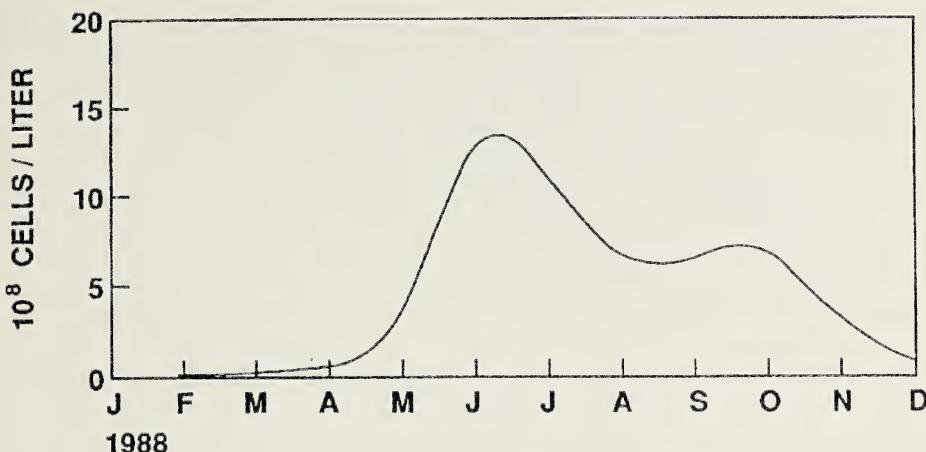


FIGURE 3. Picoplankton cell concentrations at station TF 5.5 for 1988.

tions in winter. The major component within this group was cyanobacteria, with other autotrophs being chlorophytes and several unidentified forms. Measurements of picoplankton abundance were also made at stations in the lower Chesapeake Bay during this period and indicated a pronounced single summer-early fall peak, with maximum concentrations in July (Birdsong et al. 1989).

#### CONCLUSIONS

This study of the seasonal and inter-annual variation in phytoplankton abundance at stations in the James, York and Rappahannock Rivers was based on the previous identification of three site groups in these rivers. Within the groups there was a tendency to have major periods of growth in spring, summer, or fall, with the lowest concentrations in winter. The tidal fresh water station (TF 5.5) in the James River had typically higher cell densities ( $10^7$  to  $10^8$  cells/L) than what developed in the oligo-mesohaline and mesohaline stations, with seasonal maxima seldom coinciding with those in the higher saline sections of the rivers. This is explainable on the basis of different growth responses in the regional sections of the rivers by two different sets of dominant species that were present. One is composed of fresh water species, the other has dominant estuarine and neritic species. There were also major differences in the magnitude, onset, and duration of major seasonal growth periods from year to year. Seasonal differences were associated with different sections in the same river, with concentrations and composition of the phytoplankton having distinct changes in composition and abundance during passage downstream. The transition from a dominant fresh water flora to estuarine assemblages was often rapid and accompanied by decreasing cell abundance and a pattern of reduced nutrient levels (Marshall and Alden, 1990a).

It should be stressed these patterns represent a total composite of different phytoplankton components. These abundance numbers come from several major and diverse phytoplankton categories that separately exhibit seasonal patterns of change and different periods of representation. Diatoms generally have spring and late summer-early fall peaks of abundance, cyanobacteria and picoplankton are

most abundant in summer, with the chlorophytes in early spring and summer, etc. In turn, there is also great variability in the times of maxima and minima exhibited by the individual taxa within these categories (Marshall and Alden, 1990a). In addition, results of the picoplankton analysis indicated major development occurred during summer and early fall where mean concentrations reached  $10^8$  to  $10^9$  cells/L. Factors that influence the development of these various seasonal maxima are the spring rains, nutrient replenishment, temperature changes, salt water entry, stratification and mixing events, among others (Anderson, 1986; Filardo and Dunstan, 1985; Malone, 1987; Ray et al., 1989). In addition, these rivers represent seasonally dynamic habitats, with each river having a river basin and watershed that contain a unique combination and sequence of interacting seasonal conditions. These factors may change annually, and subsequently influence the type and abundance of phytoplankton that develop in these rivers. Common phytoplankton assemblages to each rivers system may be exposed to different environmental conditions that may result in periods and magnitude of population abundance that will differ not only seasonally, but annually from each other.

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#### LITERATURE CITED

- Anderson, G. 1986. Silica, diatoms and a freshwater productivity maximum in Atlantic coastal plain estuaries, Chesapeake Bay. *Estuarine, Coastal and Shelf Sci.* 22:183-197.
- Birdsong, R., H.G. Marshall, R.W. Alden and R.M. Ewing. 1989. Chesapeake Bay Plankton Monitoring Program. Final Report for 1987-1988. Old Dominion University Research Foundation. Norfolk, Va., 151 pp.
- Filardo, M. and W. Dunstan. 1985. Hydrodynamic control of phytoplankton in low salinity waters of the James River estuary USA. *Estuarine, Coastal and Shelf Sci.* 21:653-668.
- Hecky, R.E. and P. Kilham. 1988. Nutrient limitation of phytoplankton in freshwater and marine environments: A review of recent evidence on the effects of enrichment. *Limno. and Oceanogr.* 33:796-822.
- Marshall, H.G. 1989. An appraisal of bloom producing phytoplankton in the Chesapeake Bay. Sp. Report. Virginia Environmental Endowment. Old Dominion University Research Foundation, Norfolk, Va., 27 pp.
- Marshall, H.G. and R.W. Alden. 1990a. A comparison of phytoplankton assemblages and environmental relationships in three estuarine rivers of the lower Chesapeake Bay. *Estuaries.* 13:287-300.
- Marshall, H.G. and R.W. Alden. 1990b. Spatial and temporal diatom assemblages and other phytoplankton within the lower Chesapeake Bay, U.S.A. In: H. Simola (Ed.) Proc. 10th Intern. Diatom Symp. Koeltz, Koenigstein. pp.311-322.
- Marshall, H.G. and R. Lacouture. 1986. Seasonal patterns of growth and composition of phytoplankton in the lower Chesapeake Bay and vicinity. *Estuarine, Coastal and Shelf Sci.* 23:115-130.

- McCarthy, J.J., W.R. Taylor and J.L. Taft. 1977. Nitrogenous nutrition of the plankton in the Chesapeake Bay. I. Nutrient availability and phytoplankton preferences. Limnol. and Oceanogr. 22:996-1011.
- Porter, K.G. and Y.S. Feig. 1980. The use of DAPI for identifying and counting aquatic microflora. Limnol. and Oceanogr. 25:943-948.
- Ray, R.T., L.W. Haas and M.E. Sieracki. 1989. Autotrophic picoplankton dynamics in a Chesapeake Bay sub-estuary. Mar. Ecol. Prog. Ser. 52:273-285.
- Schubel, J.R. and D.W. Pritchard. 1987. A brief physical description of the Chesapeake Bay. In: S.K. Majumdar, L.W. Hall and H.M. Austin (eds.). Contaminant Problems and Management of Living Chesapeake Bay Resources. Penn. Acad. Sci. pp.1-32.
- Sellner, K.G. 1987. Phytoplankton in the Chesapeake Bay: Role in carbon, oxygen and nutrient dynamics. In: S.K. Majumdar, L.W. Hall and H.M. Austin (eds.). Contaminant Problems and Management of Living Chesapeake Bay Resources. Penn. Acad. Sci. pp. 134-157.
- Vernick, E.L. 1978. How many cells to count. In: A. Sournia (ed.). Phytoplankton Manual. UNESCO. pp.167-180.
- Waterbury, J.B., W.W. Stanley, V.W. Frederica and D.G. Franks. 1986. Biological and ecological characterization of the marine unicellular cyanobacterium *Synechococcus*. In: T. Platt and W.K. Li (eds.). Photosynthetic picoplankton. Can. Bull. Fish. Aquat.Sci. 214:71-120.



## Spatial, Seasonal, and Interannual Patterns in the Phytoplankton Communities of a Tidal Freshwater Ecosystem

R. Christian Jones, Department of Biology

George Mason University, Fairfax, VA 22030

Claire Buchanan, Interstate Commission on the

Potomac River Basin, Rockville, MD

Victoria Andrle<sup>1</sup>, Department of Biology

George Mason University, Fairfax, VA 22030

### ABSTRACT

Phytoplankton were enumerated by species on samples collected on a biweekly to monthly basis over 6 years from 11-13 sites in the tidal freshwater Potomac River. Cell densities were analyzed by analysis of variance examining spatial, seasonal, and interannual variability. Phytoplankton densities were higher in the two embayment areas than in the river mainstem. A nearly exponential increase in phytoplankton was observed from March through August with a rapid decline in September and October. This pattern differed significantly among years resulting in a significant month-year interaction. Differences among years was also significant with the two lowest years correlating with low residence times. Loss processes, particularly flushing, appeared to be generally more important than growth processes in explaining seasonal and interannual variation. Both growth and loss factors contributed to spatial variation. Diatoms were dominant in spring and various cyanobacterial species were most important in summer.

### INTRODUCTION

The pelagic zones of tidal freshwater ecosystems provide phytoplankton with a habitat similar to that found in freshwater lakes, large rivers, and reservoirs. During periods of low freshwater inflow and long retention times, tidal freshwater systems may function as lakes with an added component of tidal movement of the water masses. During periods of high freshwater inflow, retention times may be short enough and associated factors such as turbidity high enough that large rivers may provide a better analogy. In some ways perhaps the best analogy is with reservoirs which have variable retention times depending on inflow rate and associated variations in turbidity and nutrient loading (Soballe and Kimmel, 1987).

Tidal freshwater habitats are common along the east coast of North America (Odum et al., 1984). Many of the larger rivers in this area discharge into drowned river valleys which provide a restricted basin in which to collect the freshwater inflow. Mixing with brackish water is restricted to a narrow front some distance seaward of the head of tide. The volume of water collected in the freshwater zone and the size of the resulting tidal freshwater habitat will vary depending on the balance between mixing at the seaward end and freshwater input at the landward

<sup>1</sup> Current address: 970 National Center, U.S. Geological Survey, Reston, VA 22092.

end of the basin. Clearly, the size and importance of the tidal freshwater portion of a given river system will vary with basin morphology as well as freshwater input with the latter resulting in significant seasonal variations. The volume of water comprising the tidal freshwater Potomac River varies by a factor of four seasonally from  $200 \times 10^6 \text{ m}^3$  in early fall to nearly  $800 \times 10^6 \text{ m}^3$  in late spring as a result of seasonal patterns in freshwater inflow (Lippson et al., 1979).

Phytoplankton communities in tidal freshwater should respond to factors such as light, temperature, nutrients, and hydrologic regime which show marked variation seasonally and may follow different seasonal patterns from one year to the next. In eutrophic freshwater systems previous studies indicate that seasonal maxima generally occur in spring and late summer-early fall (Marshall and Peters, 1989). Sommer et al. (1986) summarize research on the seasonal patterns in abundance in eutrophic lakes. Increased phytoplankton abundance in the spring is correlated with the onset of increased light and abundant nutrients. The decline in phytoplankton abundance in early summer is thought to be related to removal by zooplanktonic grazers and nutrient depletion. In highly eutrophic systems phytoplankton increase again in mid-summer upon relaxation of grazing stress. This summer rebound may not be found in systems where grazing pressure remains strong, summer flushing rates remain high, or nutrient concentrations are low. Eutrophic systems may be characterized in fall by either a distinct peak in abundance or a continuation of the high summer levels. The onset of winter brings low phytoplankton densities due to low light, low temperature, and possibly high flushing.

Interannual variations in climatic, edaphic, and biotic factors may result in substantial differences in seasonal abundance patterns among years. In a nine-year study of a shallow eutrophic lake, Bailey-Watts (1978) found decreasing trends in phytoplankton biomass associated with a decrease in nutrient loading and a shift to a *Daphnia*-dominated zooplankton community capable of more efficient grazing. Davis (1964) reported that spring and fall peaks in phytoplankton cell density increased in magnitude as nutrient loading increased in the early half of the 20th century in Lake Erie. By 1962 maximum values had shifted from spring to late summer-early fall. Variations in grazing intensity due to annual variations in herbivore populations or multiyear oscillations in higher trophic levels may also be important in regulating phytoplankton standing crop (Mills and Forney, 1988).

These same factors may result in marked variation spatially within the same system. Marked differences in bathymetry, flushing rates, mixing depths and nutrient loading can occur over rather small spatial scales. Cloern et al. (1983) noted that phytoplankton doubling time was almost 10 times longer in a deep river channel than in an adjacent embayment. Longitudinal gradients in primary production have been noted in a number of reservoirs related to light and nutrient availability (Kimmel et al., 1990).

Species composition of phytoplankton communities also shows seasonal, spatial and interannual variation. Numerous authors have noted the propensity of diatoms to dominate phytoplankton populations in spring, while greens and cyanobacteria are characteristic of summer populations (e.g., Welch, 1980). The affinity of diatoms for spring has been related to lower temperatures, high light levels, vigorous circulation, and abundant nutrients. In highly productive systems suc-

sional patterns during the summer growth period often lead to dominance by cyanobacteria (blue-green algae). Cyanobacteria have generally been associated with high temperatures, high pH (and low CO<sub>2</sub>), nitrogen limitation (Shapiro, 1973), favorable N:P ratios (Smith, 1983), and physically stable conditions (Paerl, 1988). In fall dominance shifts toward diatoms as temperature decreases and turbulence increases. Seasonal variations in grazing pressure and selectivity will also influence the outcome of competition among algal species (Reynolds et al., 1982; Bergquist et al., 1985).

### METHODS

Sampling was conducted at 11-13 stations monthly or semimonthly from March through November from 1984 through 1989 (Figure 1). Due to the well-mixed nature of the water column in all seasons, samples were integrated over the entire water depth. Depth-integrated samples were constructed using equal volumes of water collected by submersible bilge pump from near surface (0.3 m), mid-depth, and near bottom (0.3 m above bottom). At water depths less than 1.5 m only near surface and near bottom samples were used. Phytoplankton samples were preserved with acid Lugol's iodine to a final concentration of 1% and stored in brown glass bottles.

Phytoplankton enumeration by taxa was conducted using the inverted microscope-settling chamber method (Lund et al., 1958). At least 100 and normally several hundred cells were counted from each sample. Cells were identified to species where possible. References used for identification included Prescott (1962), Weber (1971), Van Landingham (1982), Butcher (1967), Anton and Duthie (1981), Whitford and Schumacher (1973), Smith (1950), and Huber-Pestalozz (1938, 1941, 1950).

Initial examination of the phytoplankton data indicated that stations could be grouped spatially into three regions: Gunston Cove (Stations 4, 5, 6, 7, 10, and 11), Potomac Mainstem (Stations 8, 9, 12, 14, 16, and 18), and Dogue Creek (Station 15). Samples were further classified by month and year for analysis of total phytoplankton density by ANOVA. The classification by month, year, and region resulted in some classes containing only one replicate while others had as many as 13 when there were two sampling dates in a month. For those with 2 or more replicates, mean and variance were calculated with both untransformed and log-transformed data. Log transformation was found to be necessary to stabilize the variance and total phytoplankton density was log-transformed for all statistical procedures. The pooled variance using all the log-transformed (Base 10) replicated samples was 0.105.

Patterns of numerical dominance in phytoplankton populations were analyzed by compiling a table of dominant algal taxa for each month of the year for each of the three regions of the study area. On each date average abundance was computed for each taxon for each region. When one taxon clearly dominated, it was used as the sole dominant. If other taxa were within 10% of the most numerous taxon, all were considered co-dominant. The dominant taxon for each unique combination of month, year, and region was given a value of 1. If several taxa were co-dominant, then the value was divided equally among them.

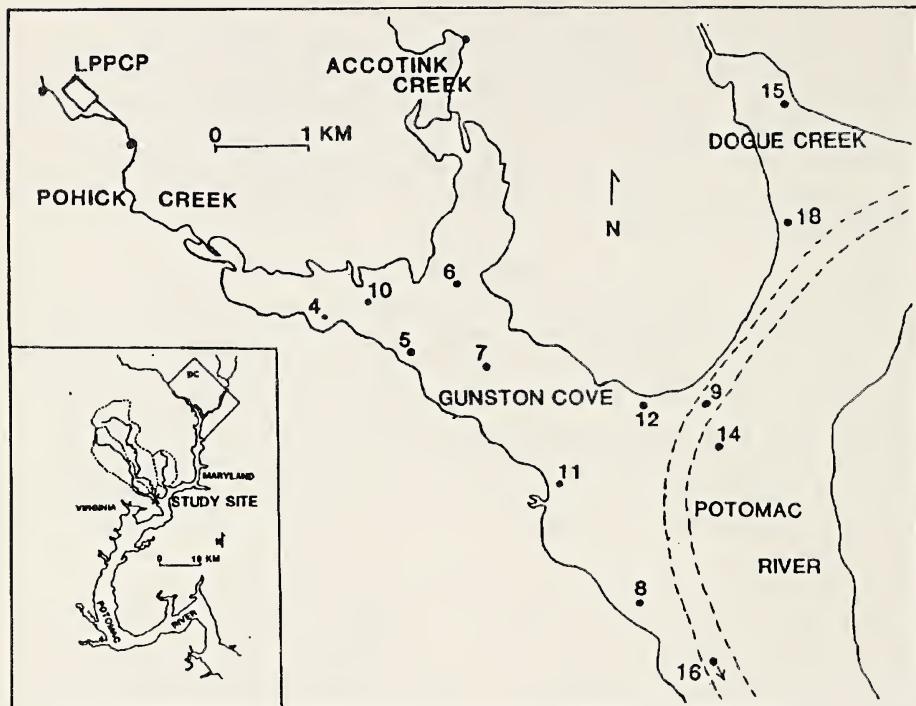


FIGURE 1. Study site showing sample locations.

## RESULTS

A simple three-way analysis of variance model using the mean values for each combination of month, year, and region resulted in highly significant main effects ( $P < 0.001$ ) for each of these factors. The model explained 78.5% of the data and the error mean square was very close to the variance determined from replicate determinations (Table 1). The grand mean over all combinations of year, month, and region was 53,580 cells/mL.

This model, which assumes no interaction between the three factors, can be examined by looking at mean values for each factor separately. A steady, exponential increase in average phytoplankton density with month was observed from March through August with a decline in September and October (Figure 2a). Phytoplankton densities were above the grand mean from June through September and below the grand mean during the spring and October. Cove stations averaged substantially above, the river substantially below and Dogue very close to the grand mean (Figure 2b). An examination of the effect of year showed that 1984 and 1989 had densities averaging below the grand mean while 1985-88 averaged above the grand mean (Figure 2c).

Although the model appeared to explain most of the variance in the data, it seemed unlikely that month, year, and region effects were so consistent that significant interactions would be totally absent. Examination of residuals from the

TABLE 1. Results of Three-way Analysis of Variance Model with Phytoplankton Density (cells/mL, log-transformed) as the response variable.

Source of Variation	Sum of Squares	df	Mean Square	F	P
Year	8.130	5	1.626	16.328	<0.001
Region	7.458	2	3.729	37.445	<0.001
Month	31.413	7	4.488	45.062	<0.001
Error	12.847	129	0.100		

simple three-way ANOVA indicated a substantially greater deviation in some of the residuals than would be expected from a normal distribution. The ANOVA was recalculated adding each of the three two-way interactions in turn to the three main effects. Only the interaction between month and year resulted in a statistically significant F value ( $P < 0.001$ ). In other words, the null hypothesis that the seasonal pattern of phytoplankton density is the same from year to year was rejected. The month-region and year-region interactions were not significant suggesting that patterns of seasonal and interyear variation are similar in all regions differing only in magnitude. The combination of the three main effects and the month-year interaction explained 90.7% of the variance in the data set (Table 2). The residual mean square from this ANOVA was even less than the variance between replicate observations. Examination of residuals from the model revealed no departures from normality.

The differences in seasonal patterns in phytoplankton densities among years are illustrated for cove stations in Figure 3. In most years there was a clear seasonal pattern in density with a steady increase from March through August and a decrease in September and October. However, in 1987 and 1989 major declines in phytoplankton density were observed in April and May, respectively. Note also that the decline in October was much stronger in 1989 than in other years. These and other differences in seasonal density patterns were responsible for the observed interaction of month with year. This figure also depicts the relationship between model predictions and observed values. Note that most observations are within about 0.2 log units of prediction.

Patterns in species numerical dominance were analyzed by month, region, and year. To illustrate overall seasonal patterns, dominance values were summed over region and year for each month (Figure 4). Diatoms were clearly the most frequent spring dominants. Of 36 observations in March and April, 30 were dominated by diatoms. The two *Microcystis*-dominated samples were in 1984 and may have been the residue of a large summer 1983 bloom in the study area. By June, diatom dominance was usually waning and cyanobacterial genera were becoming more important. *Raphidiopsis* and *Microcystis* were most frequently dominant in summer with *Raphidiopsis* showing a tendency for early summer dominance and *Microcystis* for late summer dominance. *Merismopedia*, an important summer dominant, was clearly the most common fall dominant. *Chroococcus* and *Oscillatoria* exhibited haphazard seasonal dominance patterns.

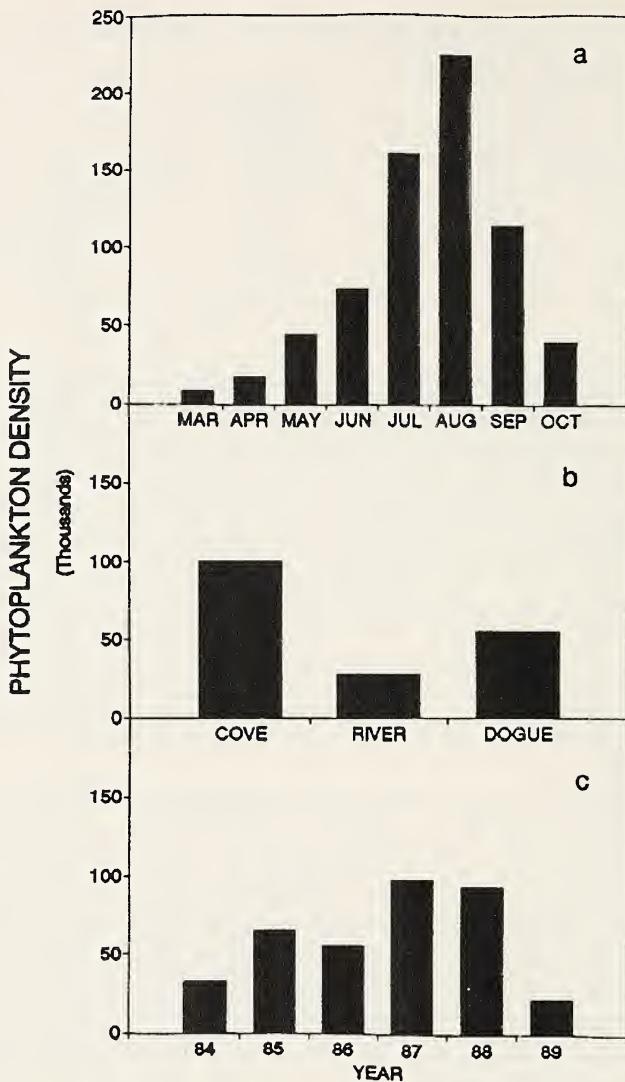


FIGURE 2. (a) Average phytoplankton density (cells/mL) by month. (b) Average phytoplankton density by region. (c) Average phytoplankton density by year.

TABLE 2. Results of Three-way Analysis of Variance Model including significant interactions with Phytoplankton Density (cells/mL, log-transformed) as the response variable.

Source of Variation	Sum of Squares	df	Mean Square	F	P
Year	8.130	5	1.626	16.328	< 0.001
Region	7.458	2	3.729	37.445	< 0.001
Month	31.413	7	4.488	45.062	< 0.001
Year*Month	7.271	35	0.208	3.503	< 0.001
Error	5.575	94	0.059		

### PHYTOPLANKTON DENSITY COVE STATIONS

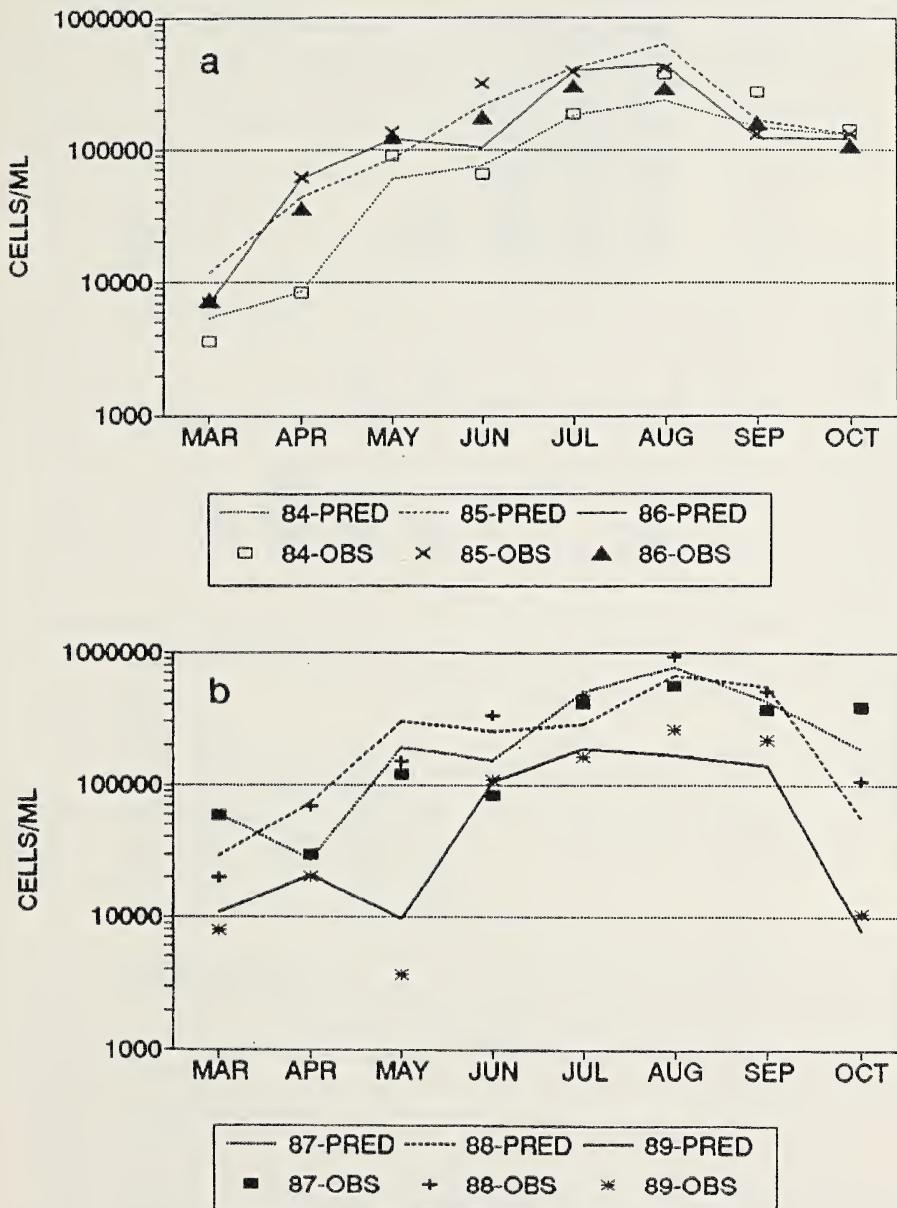


FIGURE 3. Phytoplankton density (cells/mL) at cove stations. Lines represent predictions of ANOVA model including Year-Month interactions. Symbols represent observed data. (a) 1984-86. (b) 1987-89.

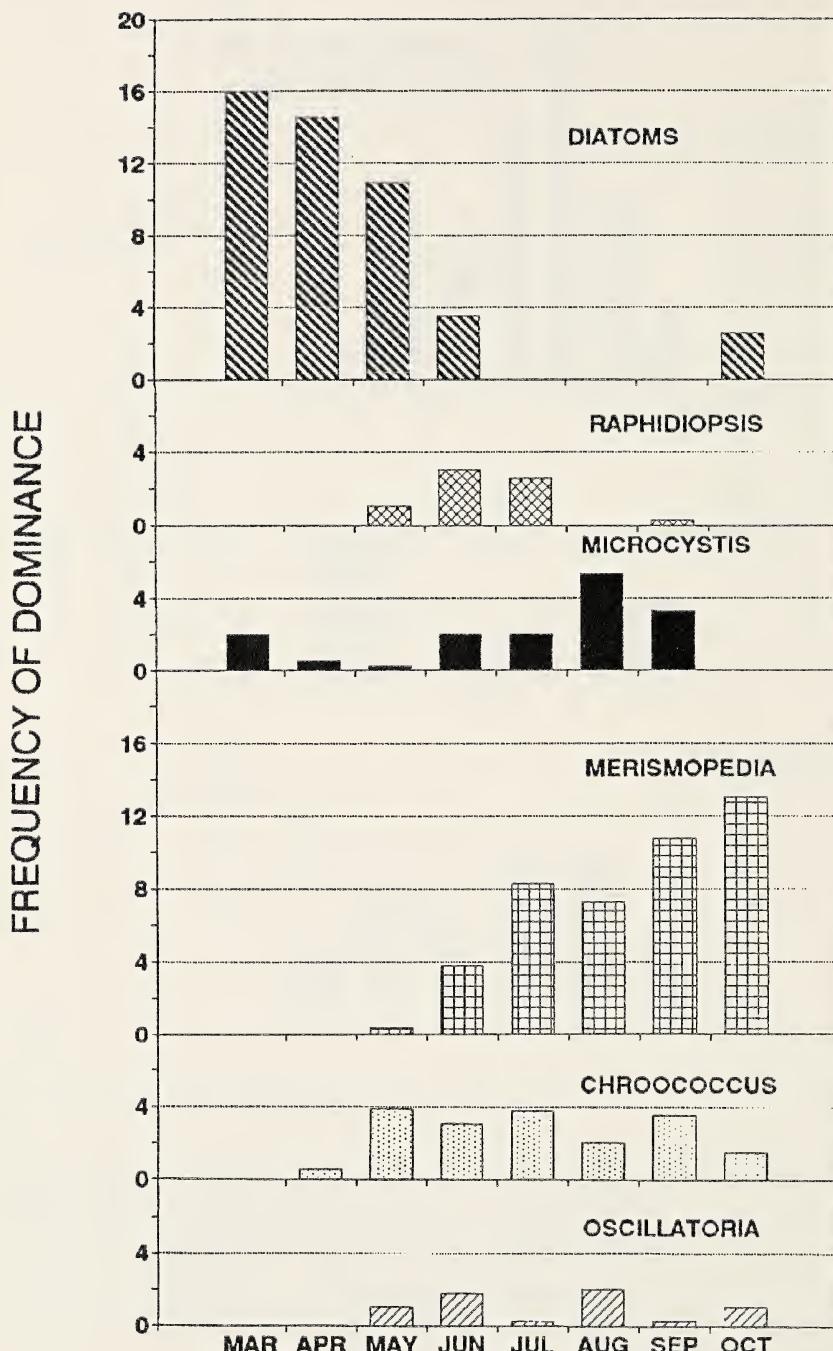


FIGURE 4. Frequency of numerical dominance (number of year-regions) of each taxa by month.

Regional patterns were assessed by summing dominance values over month and year (Figure 5). Diatoms were most frequently dominant at Dogue Creek and least frequently dominant in Gunston Cove. *Raphidiopsis* and *Oscillatoria* showed a pattern of greatest dominance in the Cove followed by substantial dominance in the river, but negligible dominance in Dogue. *Microcystis* was most frequently dominant in the cove, but was dominant in the river and Dogue on a few occasions. *Chroococcus* was more frequently dominant in the river than Dogue and the cove. *Merismopedia* was dominant in all study regions, but was most frequently dominant in Dogue. In fact, either diatoms or *Merismopedia* dominated almost all of the samples from Dogue. Dominance in the other two regions was more evenly distributed among the taxa.

Interannual trends were examined by summing dominance values over month and region (Figure 6). Diatoms showed the least variation in dominance frequency among years. *Merismopedia* displayed a tendency to increase dominance with year except for 1987. *Chroococcus* showed marked interannual variation in dominance with peak years in 1986 and 1987. *Oscillatoria* achieved appreciable dominance only in 1984, 1987, and 1988. *Raphidiopsis* was dominant only in the early years of the study. *Microcystis* was variable in dominance but was represented in all years except 1989. *Microcystis* exhibited major bloom outbreaks in the cove all years from 1985 through 1988. However, in most of these years the bloom was restricted to the cove and may have occurred for only one month. This was the case in 1986 and 1987. On the other hand, high dominance was found in 1984 when no large *Microcystis* bloom was observed. This was the result of *Microcystis* dominance during non-bloom periods. *Oscillatoria* appeared sporadically with major outbreaks in 1984, 1987 and 1988. In most years at least four taxa contributed to dominance. However, in 1989 virtually all samples were dominated by *Merismopedia* or diatoms.

Several taxa not found in Figures 4-6 were dominant on occasion. Green algae were dominant or co-dominant in April 1987 over the entire study area. *Coelosphaerium* was dominant or co-dominant in the cove in July of two years. Cryptophytes, *Phormidium*, and *Aphanizomenon* were dominant or co-dominant on at least one occasion.

## DISCUSSION

The seasonal pattern of phytoplankton abundance observed in this study appears to contradict that reported for most eutrophic systems in that no late spring-early summer decline was noted. In fact phytoplankton densities generally sustained a nearly exponential increase from March through August. The lack of a decline during this period suggests that conditions for growth (light, temperature, nutrient availability) remain favorable and that loss factors (grazing, flushing, sedimentation) do not normally exceed growth.

Temperature certainly increases through the growth period, but solar radiation reaches a maximum in late June and by August is much reduced. Nutrient availability remains high with total phosphorus averaging 50-150  $\mu\text{g/L}$  and total nitrogen 1.5-7.5 mg/L (Jones and Kelso, 1990). Crustacean zooplankton, the major planktonic grazers, reach maximum levels in late May and early June during the time of increasing phytoplankton densities. Thus, their feeding does not appear to

FREQUENCY OF DOMINANCE

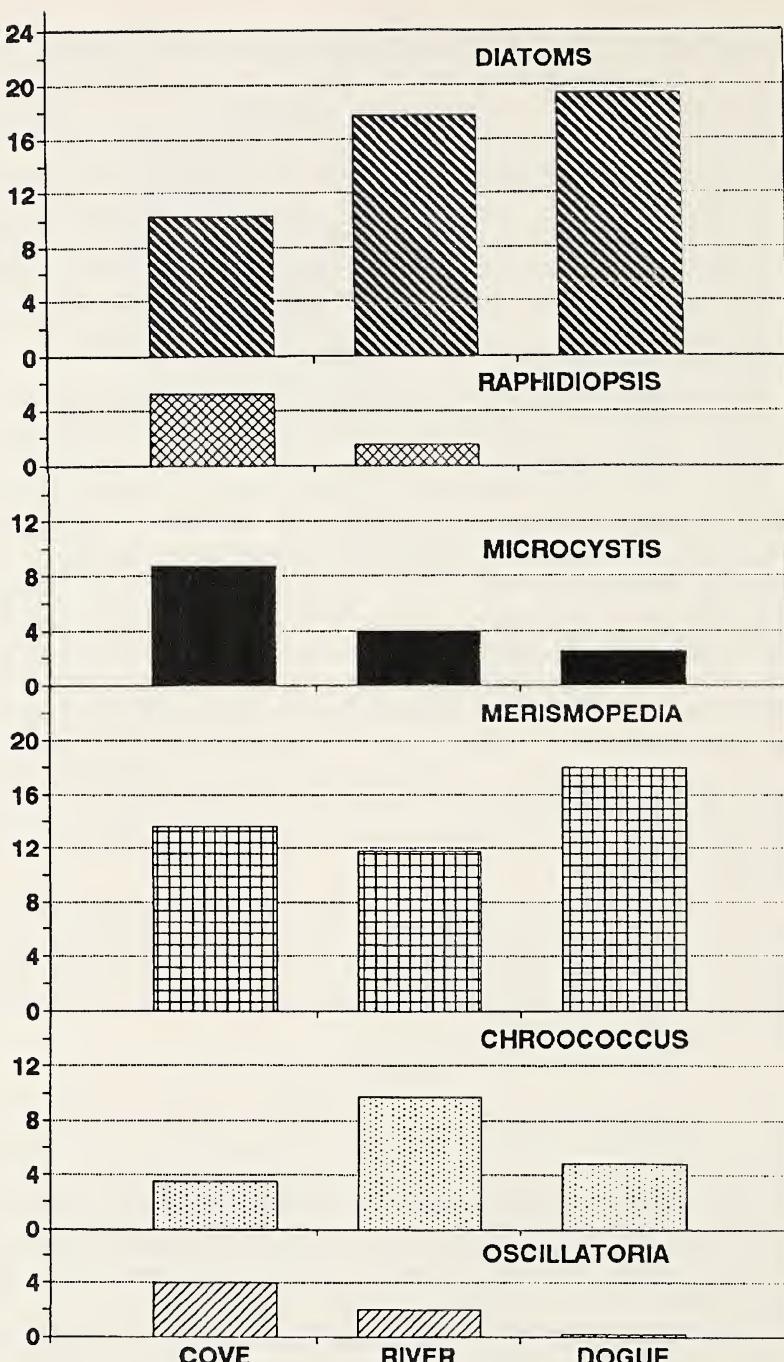


FIGURE 5. Frequency of numerical dominance (number of month-years) of each taxa by region.

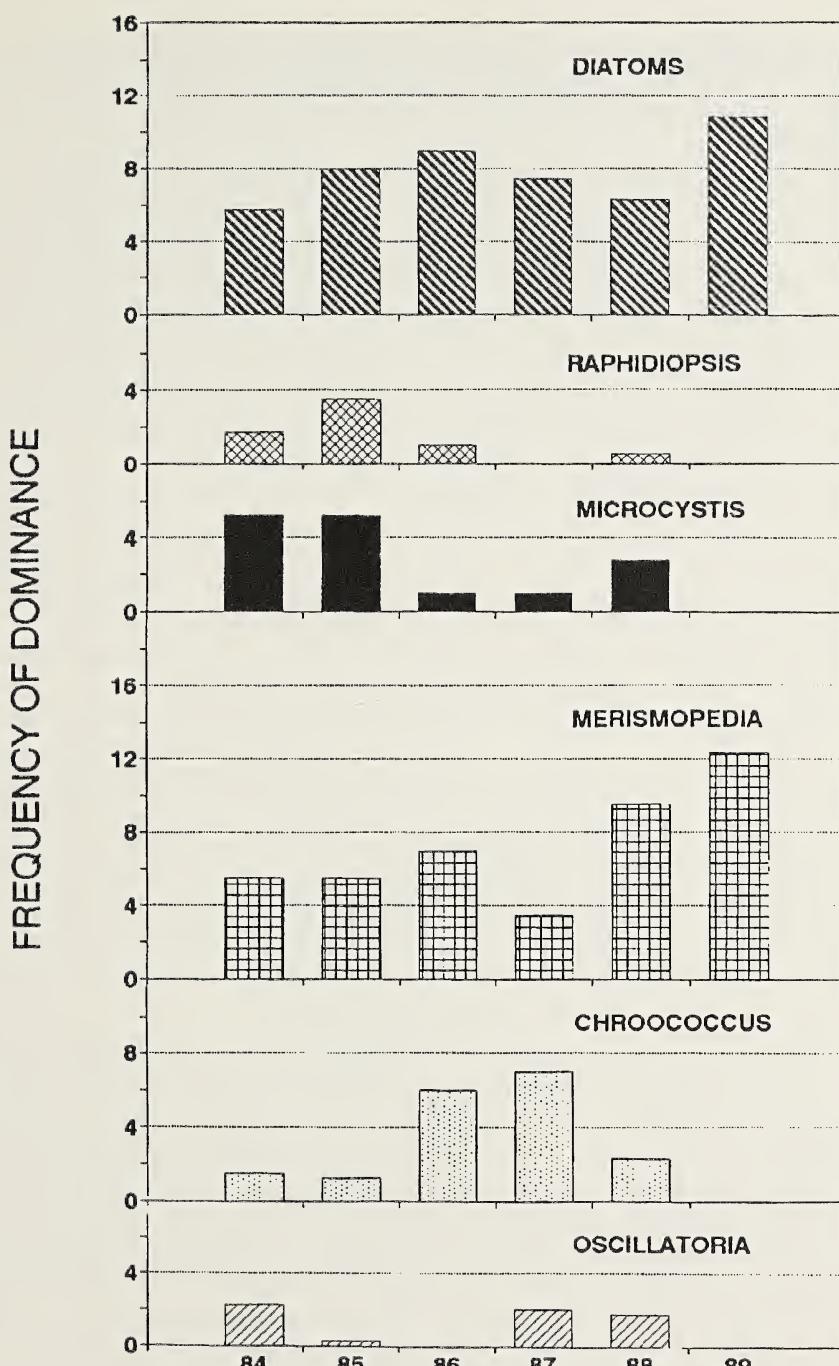


FIGURE 6. Frequency of numerical dominance (number of month-regions) of each taxa by year.

limit phytoplankton growth. Data are not available on seasonal sedimentation patterns. However, it is reasonable to suggest that these would be greatest during the lowest river flow periods of late summer which is also the time of highest standing crop.

One loss factor that does seem to be correlated with seasonal patterns of phytoplankton density is water residence time. Water residence time in Gunston Cove varies from 1-10 days in spring to 100-1000 days in late summer. Flushing also appears to be responsible for some of the major deviations from the simple seasonal model. A substantial drop in phytoplankton density in May 1989 was closely related to a dramatic decrease in water residence time to less than one day. Obvious departures from mean levels observed in April 1987 and October 1989 were also associated with a decline to less than 2 days in cove residence time. Thus, flushing may be a significant factor in both the normal seasonal pattern of phytoplankton density and in deviations from this pattern during certain years.

The clear effect of region on phytoplankton density may be related to both growth and loss factors. The shallower water column in the embayment areas of Dogue and Gunston provides a higher average light level for circulating phytoplankton leading to greater photosynthetic and growth potential than in the much deeper river mainstem. Nutrient concentrations are generally higher in Gunston than in the river (Jones and Kelso, 1990), but similar in Dogue and the river. This may help explain the intermediate position of Dogue Creek.

Regional variation in loss factors is more difficult to assess. Flushing of the Cove is probably dependent on local tributary inflow, whereas hydraulic inputs to the river mainstem are controlled by runoff from a much larger area upstream. This could result in a temporal difference in flushing rates between the two areas. Interestingly, the interaction of region with month was not significant indicating that temporal differences in flushing between regions, if present, were not of overriding significance. Available data suggest that grazing losses in the study area are not excessive. Buchanan and Schloss (1983) estimated summer zooplankton clearance rates at generally less than 5% of river volume per day in the tidal freshwater Potomac mainstem. Furthermore, densities of crustacean zooplankton are generally greater in the embayments than in the river, the opposite of what would be expected if their grazing were responsible for regional differences in phytoplankton densities. It should be noted that cyanobacteria, the dominant phytoplankters during most of the year, are not efficiently grazed by most zooplankton (Fulton and Paerl, 1987). Another potentially important filter feeder, the bivalve *Corbicula fluminea*, is found in much higher concentrations in the river mainstem and may help explain the lower densities found there. Cohen et al. (1984) suggested that grazing by *Corbicula* in the Potomac river mainstem may be substantial enough to strongly depress phytoplankton populations. We have recently observed large populations of colonial rotifers on macrophytes lining the river channel which are capable of rapidly reducing phytoplankton populations in laboratory experiments (Jones, unpublished data).

The interannual variations observed seem to be related mostly to variations in loss factors. Freshwater inflow, both local to the cove and more broadly to the entire tidal Potomac, varied substantially among years. The two years with lowest average phytoplankton density had the highest frequency of high discharge days during the

growing season. Potomac River flows exceeded 10,000 cfs on 15 days during the period June 15-August 31 in 1984 and on 36 days during a similar period in 1989. This level was exceeded no more than 4 days during the same period in any other study year. Likewise, discharges directly to the cove more frequently exceeded a daily average of 300 cfs (equivalent to a 2-day cove residence time) in 1984 and 1989 than in the intervening years.

The years 1984 and 1989 also differed from intervening years by the lack of a bloom of the cyanobacterium *Microcystis aeruginosa*. These blooms have been hypothesized to begin with prolonged periods of hot, calm weather which promotes the development of *Microcystis*. Blooms of this cyanobacterium are capable of attaining large numbers and raising pH to unusually high levels (Jones, 1991) presumably by CO<sub>2</sub> removal. At these pH levels phosphorus is released at high rates from the sediments (Kircher 1990; Ochrlein, 1990) fueling unusually high phytoplankton densities approaching or exceeding  $1 \times 10^6$  cells/mL. The difference would probably have been greater if biomass had been examined since *Microcystis* has somewhat larger cells than the dominant cyanobacteria in non-bloom years.

The seasonal pattern of species dominance is similar to that observed in eutrophic freshwaters with diatoms dominant in spring and cyanobacteria in summer and fall. These patterns also correlate well with environmental conditions said to favor these two groups. High turbulence in spring allows diatoms to avoid the problems of sedimentation during this period when temperature and light levels favor their growth. Cyanobacterial dominance in the summer may be aided by high pH's (up to 11.0) and temperatures.

It should be noted that dominance in this paper was calculated based on cell density basis. Preliminary calculations of biovolume indicate that cyanobacteria are less important to phytoplankton biomass than cell count data would indicate and that in some cases other groups such as cryptophytes and green algae are actually dominant in biovolume at times of cyanobacterial dominance in cell density. Work is currently underway to calculate species abundance by biovolume which may resolve this uncertainty.

#### ACKNOWLEDGEMENTS

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#### LITERATURE CITED

- Bailey-Watts, A.E. 1978. A nine-year study of the phytoplankton of the eutrophic and non-stratifying Loch Leven (Kinroll, Scotland). J. Ecol. 66: 741-771.
- Bergquist, A.M., S.R. Carpenter, and J.C. Latino. 1985. Shifts in phytoplankton size structure and community composition during grazing by contrasting zooplankton assemblages. Limnol. Oceanogr. 30: 1037-1045.

- Buchanan, C. and J.A. Schloss. 1983. Spatial distributions and hypothetical grazing pressures of zooplankton in the tidal, freshwater Potomac River. *J. Freshwater Ecol.* 2: 117-128.
- Butcher, R.W. 1967. An Introductory Account of the Smaller Algae of the British Coastal Waters. Part IV. Cryptophyceae. London: Her Majesty's Stationery Office.
- Campbell, P.H. 1973. Studies on Brackish Water Phytoplankton. Sea Grant Publication UNC-SG-73-07.
- Cloern, J.E., A.E. Alpine, B.E. Cole, R.L.J. Wong, J.F. Arthur, and M.D. Ball. 1983. River discharge controls phytoplankton dynamics in the northern San Francisco Bay estuary. *Estuar. Coast. Shelf Sci.* 16: 415-429.
- Cohen, R.R.H., P.V. Dresler, E.J.P. Phillips and R.L. Cory. 1984. The effect of the Asiatic clam, *Corbicula fluminea*, on phytoplankton of the Potomac River, Maryland. *Limnol. Oceanogr.* 29: 170-180.
- Davis, C.C. 1964. Evidence for the eutrophication of Lake Erie from phytoplankton records. *Limnol. Oceanogr.* 9: 275-283.
- Fulton, R.S., and H.W. Paerl. 1987. Effects of colonial morphology on zooplankton utilization of algal resources during blue-green algal (*Microcystis aeruginosa*) blooms. *Limnol. Oceanogr.* 32: 634-644.
- Huber-Pestalozz, G. 1938. Das Phytoplankton des Süsswassers. Band XVI. Teil 1. Die Binnengewässer. Schweizerbart'sche Verlagsbuchhandlung.
- Huber-Pestalozz, G. 1941. Das Phytoplankton des Süsswassers. Band XVI. Teil 2. Die Binnengewässer. Schweizerbart'sche Verlagsbuchhandlung.
- Huber-Pestalozz, G. 1950. Das Phytoplankton des Süsswassers. Band XVI. Teil 3. Die Binnengewässer. Schweizerbart'sche Verlagsbuchhandlung.
- Jones, R.C. and D.P. Kelso. 1990. An ecological study of Gunston Cove: 1989-90. Final Report submitted to Fairfax County, Virginia. 280 pp.
- Jones, R.C. 1991. Spatial and temporal patterns in a cyanobacterial phytoplankton bloom in the tidal freshwater Potomac River, U.S.A. *Verh. Internat. Verein. Limnol.* 24: 1698-1702.
- Kimmel, B.L., O.T. Lind, and L.J. Paulson. 1990. Reservoir primary production. Pages 133-194 in Thornton, K.W., B.L. Kimmel, and F.E. Payne. (eds.) Reservoir Limnology: Ecological Perspectives. Wiley-Interscience. 246 pp.
- Kircher, S.R. 1990. The effect of pH on the release of phosphorus from the sediments of Gunston Cove, Virginia. M.S. Thesis. George Mason University, Fairfax, VA. 49 pp.
- Lippson, A.J., M.S. Haire, A.F. Holland, F. Jacobs, J. Jensen,, R.L. Moran-Johnson, T.T. Polgar, and W.A. Richkus. 1979. Environmental Atlas of the Potomac Estuary. Johns Hopkins University Press. 280 pp.
- Lund, J.W.G., C. Kipling, and E.D. LeCren. 1958. The inverted microscope method of estimating algal numbers and the statistical basis of estimations by counting. *Hydrobiologia* 11: 143-170.
- Marshall, C.T. and R.H. Peters. 1989. General patterns in the seasonal development of chlorophyll a for temperate lakes. *Limnol. Oceanogr.* 34: 856-867.
- Mills, E.L. and J.L. Forney. 1988. Trophic dynamics and development of freshwater pelagic food webs. Pages 11-330 in: Complex Interactions in Lake Communities. S.R. Carpenter (ed). Springer-Verlag. 283 pp.

- Odum, W.E., T.J. Smith, J.K. Hoover, and C.C. McIvor. 1984. The Ecology of Tidal Freshwater Marshes of the United States East Coast: A Community Profile. U.S. Fish and Wildlife Service. FWS/OBS-83/17.
- Oehrlein, W.L. 1990. Sediment phosphorus available to phytoplankton as a function of pH in Pohick Bay, Virginia. M.S. Thesis. George Mason University, Fairfax, Virginia. 43 pp.
- Pearl, H. W. 1988. Nuisance phytoplankton blooms in coastal, estuarine, and inland waters. *Limnol. Oceanogr.* 33:823-847.
- Prescott, G.W. 1962. Algae of the Western Great Lakes Area. Brown.
- Reynolds, C.S., J.M. Thompson, A.J.D. Ferguson, and S.W. Wiseman. 1982. Loss processes in the population dynamics of phytoplankton maintained in closed systems. *J. Plankton Res.* 4: 61-600.
- Shapiro, J. 1973. Blue-green algae: why they become dominant. *Science* 179: 382-384.
- Smith, G.M. 1950. The Freshwater Algae of the United States. McGraw-Hill Book Co. 719 pp.
- Smith, V.H. 1983. Low nitrogen to phosphorus ratios favor dominance by blue-green algae in lake phytoplankton. *Science* 221: 669-671.
- Soballe, D.M. and B.L. Kimmel. 1987. A large-scale comparison of factors influencing phytoplankton abundance in river, lakes, and impoundments. *Ecology* 68: 1943-1954.
- Sommer, U., Z.M. Gliwicz, W. Lampert, and A. Duncan. 1986. The PEG-model of seasonal succession of planktonic events in Freshwaters. *Arch. Hydrobiol.* 106: 433-471.
- VanLandingham, S.L. 1982. Guide to the Identification, Environmental Requirements and Pollution Tolerance of Freshwater Blue-green Algae (Cyanophyta). US Environmental Protection Agency 600/3-82-073. PB83-163006. 340 pp.
- Weber, C.I. 1971. A Guide to the Common Diatoms at Water Pollution Surveillance System Stations. US Environmental Protection Agency, Cincinnati, Ohio, USA.
- Whitford, L.A. and G.J. Schumacher. 1973. A Manual of Freshwater Algae. Sparks Press, Raleigh, N.C.



## Investigation of Barge-associated Mortality of Larval Fishes in the Kanawha River

Michael C. Odom, Donald J. Orth, and Larry A. Nielsen

Department of Fisheries and Wildlife Sciences

Virginia Polytechnic Institute and State University

Blacksburg, Virginia 24061-0321

### ABSTRACT

Field studies were conducted to assess barge-associated mortality of larval fish in the Winfield Pool, Kanawha River, West Virginia. Bongo nets were used to collect larval fish from the sailing line before and immediately after barge passage in June and July 1983. The percent of live larvae in samples taken before and after barge passage did not differ significantly for either sampling period. High handling mortality and variation in percent of live larvae among samples may have masked any barge effects.

### INTRODUCTION

Increases in commercial navigation on the Mississippi River and its tributaries (ANSF 1980; UMBRC 1982; USACE 1983) has stimulated concern about the impacts vessel passage may have on fish communities (Nielsen et al., 1986). Due to their small size and planktonic nature, fish eggs and larvae within the sailing line may be subject to a variety of lethal forces including hull shear (Morgan et al., 1976), entrainment through the propulsion mechanism (abrupt changes in hydrostatic pressure and shear forces), and exposure to the turbulent high velocities within the propeller wash. Ichthyoplankton along the shoreline may be subject to lethal drawdowns created by approaching barges (Holland, 1987) and vessel-generated waves breaking along the shore (Bhowmik et al., 1982). Few laboratory and field investigations of effects on ichthyoplankton have been done (Morgan et al., 1976; Holland, 1986; Holland, 1987; Killgore et al., 1987); consequently, no generalizations of the severity of impacts have been documented.

Direct mortality of fish larvae caused by barge passage has not been documented. The field conditions for detecting damage to small, delicate, widely-dispersed organisms in large flowing-water systems in the presence of large vessels moving at high speeds hinders assessment efforts. In the only published field study, Holland (1986) detected direct effects, in the form of visible damage, on freshwater drum (*Aplodinotus grunniens*) eggs but not on larvae. Abundant algae in the Mississippi River filled ichthyoplankton samples, preventing Holland (1986) from separating live and dead larvae; consequently, captured larvae were preserved in formalin and examined later for signs of damage.

This research was designed to investigate barge-related direct mortality of larval fish within the sailing line of the main channel of the Kanawha River, West Virginia, utilizing the standard technique of collecting larvae in towed plankton nets.

### STUDY AREA

The Kanawha River (sixth-order stream formed by the confluence of the New and Gauley Rivers in south-central West Virginia) flows northwesterly to the Ohio River at Point Pleasant, West Virginia. Most of its 188 km are made navigable by

locks and dams which create four navigational pools. Average annual discharge at Charleston, West Virginia, on the Winfield Pool (area 29,985 sq km) was 424.8 m<sup>3</sup>/s from 1939 to 1983 (Embree et al. 1984). On sampling dates the discharge was 248 m<sup>3</sup>/s (June) and 217 m<sup>3</sup>/s (July).

The Winfield Pool (river km 50-109) is a heterotrophic system dependent upon allochthonous energy sources (Hershfeld et al., 1986). Deciduous vegetation lines the shoreline except within industrial sections of the Charleston area. The Winfield Pool is lotic and lacking backwaters at the upstream end, grading to a more lentic nature with frequent small embayments (inundated tributaries) in the downstream end. The predominant substrate within the Winfield Pool grades from cobble and pebble in the upper end, to sand and silt in the downstream portion. Aquatic macrophytes are rare. The shoreline zone is characterized by overhanging riparian vegetation, occasional fallen trees extending out into the river, sunken and partially buried logs and woody debris, riprap, and an abundance of industrial and residential refuse. Due to reduced velocities in this zone, the shoreline substrate is primarily sand and silt mixed with organic matter. The fish assemblage contains 65 species (Hershfeld et al., 1986). Fish biomass is dominated by gizzard shad (*Dorosoma cepedianum*), common carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), and smallmouth buffalo (*Ictiobus bubalus*); numerical abundance is dominated by emerald shiner (*Notropis atherinoides*), gizzard shad, mimic shiner (*Notropis volucellus*), and spottail shiner (*Cyprinella spiloptera*). The sport fishery is dependent upon channel catfish, *Micropterus* spp. basses, sauger (*Stizostedion canadense*), freshwater drum, and white bass (*Morone chrysops*).

A sampling site was selected in the lower portion of the Winfield Pool between river km 55 and 59.5 where traffic was heaviest. The river width at the site is approximately 225 m with a midchannel depth of approximately 9.4 m. Water depth does not change noticeably with discharge except during unusually large floods. The site has steep banks and a relatively uniform depth.

#### METHODS

Mortality of fish larvae in the vicinity of moving barges was evaluated by comparing mortality in samples collected before and immediately after barge passage. Sampling was conducted during 16-17 June, and 7-9 July 1983, periods when larval fish densities were high (>15/100 m<sup>3</sup>). All sampling was conducted in the sailing line. In June, 11 pre-passage and 9 post-passage samples were collected at three depths in the sailing line (near surface, mid-depth, and near bottom). In July, 21 pre-passage and 13 post-passage samples were collected near surface and at mid-depth.

Samples were collected by towing behind a twin bridleless 0.5-m diameter bongo nets (0.5-mm mesh) for 5 min at 85 cm/s. Pre-passage samples were collected before barge passage and no less than 1 h after the passage of a barge. When a barge entered the sampling area, a tow was made beginning approximately 100 m behind the barge, and proceeding in the same direction of travel. Upon completion of the tow, the sample was rushed to the sorting crew for immediate processing. The sampling boat then caught up to the barge and collected another sample. Two or three samples could be collected in this way before the barge left the mortality sampling area.

The sorting crew sorted fish into live and dead larvae within 20 min of tow completion. Larvae were examined and classified as live or dead based on mobility. They were counted and fixed in 5-10% buffered formalin.

Each period's samples were pooled across depths and a Wilcoxon rank sum test (Hollander and Wolfe, 1973) was employed to determine if mortality differed between collections taken before and after barge passage. An alpha level of 0.05 was used for statistical significance in these tests.

## RESULTS

Percentages of live larvae were low in pre-passage and post-passage samples, and did not differ significantly at the 0.05 level for either June or July (Table 1). In June, when samples were dominated by small gizzard shad larvae (81% of catch), mean percentages of live larvae decreased from 32% before to 18% after barge passage, but the difference was not significant ( $P = 0.074$ ). In July, gizzard shad comprised 23% of the catch, being replaced by freshwater drum and minnows (Cyprinidae) as the dominant components (45% and 28% of catch, respectively). The mean percentage of live larvae following barge passage at this time appeared higher than in pre-passage samples, but the difference was not significant ( $P = 0.123$ ). The mean sizes of larvae were similar in the June and July sampling periods.

## DISCUSSION

The results of this study illustrate the difficulty of larval fish impact assessment. Conservative risk assessments may assume as much as 100% mortality of larvae entrained through barge propulsion mechanisms. However, vessel-related mortality has been surprisingly difficult to detect in the field. Our inability to document barge-related direct mortality of larval fish is similar to the findings of Holland (1986), despite our separation of live and dead larvae immediately after collection.

Four explanations for our inability to document vessel-related mortality may be plausible. First, barges may not kill or damage significant numbers of larvae in the Kanawha River. Holland (1986) observed that for a significant increase in damaged eggs of freshwater drum, followed barge passage, but a similar trend for larvae was not evident. Morgan et al. (1976) reported striped bass (*Morone saxatilis*) larvae survived experimental shear forces better than eggs. Therefore, for some species, larvae may be more tolerant than eggs to vessel-related perturbations. Similar information for eggs and larvae of other species common to the Mississippi River drainage is not available.

Second, Holland (1986) suggested that mixing of non-impacted larvae with impacted larvae within the barge wake may dilute the damaged larvae to an imperceptible percentage. This implies that larvae have a lower barge-associated mortality than eggs; otherwise Holland (1986) would not have found a significant increase in damaged eggs following barge passage.

Third, high and variable handling mortality of larvae associated with plankton nets may have masked differences in barge-related mortality. If sampling mortality were zero, for example, then a 10% barge-induced mortality would cause a 10% difference in total mortality. With a 70% sampling mortality, however, the difference in total mortality would be only 3%. Given the variation in observed catches and mortality rates, a 3% difference is virtually undetectable.

TABLE 1. Two-sided Wilcoxon Rank Sum tests on barge-induced larval fish mortality data.

	June		July	
	Before	After	Before	After
Number of replicates:	11	9	21	13
Mean larvae/replicate:	55.4	44.0	38.7	28.5
SD (larvae/replicate):	50.7	21.6	24.9	15.9
Mean % live larvae:	31.9	18.3	21.5	31.0
SD (% live larvae):	14.9	16.2	14.3	20.4
<i>P</i> -value:	0.074		0.123	

Fourth, the sampling methodology used in this study (towed plankton nets), as well as that employed by Holland (1986), may have an additional shortcoming in assessing barge-associated mortality of larvae. Avoidance of nets by larvae is considered to be triggered by visual clues and pressure waves moving ahead of towed nets. The pre-passage samples were collected in relatively calm water, whereas the post-passage samples were collected in the turbulent wake of barges. Turbidity levels may increase following barge passage, reducing visibility, and turbulence within the wake may disguise the pressure waves of an oncoming net. Reduced avoidance capability could result in a higher percentage of live larvae being captured than if the water's physical conditions matched those existing when the pre-passage samples were taken.

Future investigations of direct impacts on larval fishes by barge passage should consider alternate sampling methods. Although standard plankton nets are efficient in filtering large volumes of water, mortality is relatively high in captured larvae. Large diameter plankton nets pushed at low velocities ahead of a sampling boat (e.g., Kriete and Loesch, 1980; Siler, 1983; Tinsley et al., 1989) may be an acceptable compromise between low handling mortality and the need to filter large volumes of water, but such a gear type would need to be developed especially for this purpose. Until a better sampling technique is developed and employed, it is unlikely that the controversy regarding vessel impacts to larval fish will be adequately addressed.

#### ACKNOWLEDGMENTS

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#### LITERATURE CITED

ANSP (Academy of Natural Sciences of Philadelphia). 1980. Analysis of the effect of tow traffic on the biological components of the Ohio River. Final rep. U.S. Army Corps of Engineers, Huntington, West Virginia.

- Bhowmik, N. G., M. Demissie, and C. Guo. 1982. Waves generated by river traffic and wind on the Illinois and Mississippi River. Water Resour. Ctr., Univ. Ill., Res. Rep. No. 167, Urbana, Illinois.
- Embree, W. N., E. A. Friel, F. M. Taylor, and T. A. Ehlke. 1984. Water resources data for West Virginia, water year 1983. U.S. Geological Survey Water-Data Report WV-83-1. U.S. Geological Survey, Charleston, West Virginia.
- Hershfeld, D. C., D. J. Orth, and L. A. Nielsen. 1986. Fish production in the Kanawha River and its relation to barge traffic. Pol. Arch. Hydrobiol. 33:295-303.
- Holland, L. E. 1986. Effects of barge traffic on distribution and survival of ichthyoplankton and small fishes in the upper Mississippi River. Trans. Am. Fish. Soc. 115:162-165.
- Holland, L. E. 1987. Effect of brief navigation-related dewaterings on fish eggs and larvae. N. Am. J. Fish. Manage. 7:145-147.
- Hollander, M., and D. A. Wolfe. 1973. Nonparametric statistical methods. John Wiley & Sons, Inc., New York.
- Killgore, K. J., A. C. Miller, and K. C. Conley. 1987. Effects of turbulence on yolk-sac larvae of paddlefish. Trans. Amer. Fish. Soc. 116:670-673.
- Kriete, W. H., Jr., and J. G. Loesch. 1980. Design and relative efficiency of a bow-mounted pushnet for sampling juvenile pelagic fishes. Trans. Am. Fish. Soc. 109:649-652.
- Morgan, R. P., II, R. E. Ulanowicz, V. J. Rasin, Jr., L. A. Noe, and G. B. Gray. 1976. Effects of shear on eggs and larvae of striped bass, *Morone saxatilis* and white perch, *M. americana*. Trans. Amer. Fish. Soc. 105:149-154.
- Nielsen, L. A., R. J. Sheehan, D. J. Orth. 1986. Impacts of navigation on riverine fish production in the United States. Pol. Arch. Hydrobiol. 33:277-294.
- Siler, J. R. 1983. Description of a trawl handling structure for a bow-fished Tucker trawl. Prog. Fish-Cult. 45:217-220.
- Tinsley, V. R., L. A. Nielsen, and D. H. Wahl. 1989. Pushnet sampling as a supplement to seine sampling in rivers. Fish. Res. 7:201-206.
- UMRBC (Upper Mississippi River Basin Commission). 1982. Comprehensive master plan for the management of the upper Mississippi River system. Minneapolis, Minnesota.
- USACE (U.S. Army Corps of Engineers). 1983. Kanawha River navigation study, reconnaissance report and appendices. Huntington, West Virginia.
- VPISU (Virginia Polytechnic Institute and State University). 1985. Development and application of an energy flow model to analyze impacts of navigation changes on the Kanawha River in West Virginia. Final report to U.S. Army Corps of Engineers, Huntington, West Virginia.



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## Distribution of the Endangered Glassy Darter, *Etheostoma vitreum*, in Maryland Coastal Plain Streams

Steven A. Fischer, Lenwood W. Hall, Jr., and  
William D. Killen, Jr.

University of Maryland System, Maryland Agricultural Experiment Station, Wye Research and Education Center, Queenstown, Maryland 21658

### ABSTRACT

The glassy darter, *Etheostoma vitreum*, is currently considered an endangered extirpated species in Maryland. Recently, *Etheostoma vitreum* was collected from several streams within the Marshyhope Creek drainage basin on the Delmarva peninsula of Maryland. Although this is a range extension for this species in Maryland, it is most likely the result of a paucity of historical fish taxonomic surveys on the Delmarva peninsula. *Etheostoma vitreum* was collected from only one Maryland stream known to have historical populations. Suitable habitat for *E. vitreum* consisted of first to third-order streams with sand and gravel substrates. Collections of *E. vitreum* were made only from streams with pH greater than 6.5, acid neutralization capacity greater than 250  $\mu\text{eq/L}$ , conductivity greater than 65  $\mu\text{s/cm}$ , turbidity (baseflow) less than 15 NTU, and in waters less than 0.5 m in depth.

### INTRODUCTION

The glassy darter, *Etheostoma vitreum*, is currently listed as an endangered extirpated species in Maryland (MDNR, 1991). This classification indicates that viable *E. vitreum* populations previously existed in the State of Maryland, but naturally occurring populations do not presently exist. Lee et al. (1980) indicated that *E. vitreum* historically ranged from the Neuse River drainage of North Carolina, to the Patuxent River drainage (western shore) of Maryland. A population of approximately 1000 *E. vitreum* was reported to inhabit Western Branch Creek in Prince George's County, Maryland, in the late 1950's (Winn and Picciolo, 1960). Mansueti (1950) and Tsai and Golembiewski (1979) reported the collection of *E. vitreum* from several locations in the Patuxent River drainage basin. The collection of *E. vitreum* from Winters Run, Harford County, Maryland, reportedly represented the northern range limit (Lee et al., 1980).

*Etheostoma vitreum* is most commonly associated with small to medium-sized streams, with sand and gravel substrates (Lee et al., 1980). Winn and Picciolo (1960) reported *E. vitreum* adults spend the majority of their time with their posterior buried in sand. Adults were found to inhabit shifting sand substrates until early fall, at which time they moved into deeper pools for the winter months (Winn and Picciolo, 1960). Several morphological adaptations, such as large pectoral fins, a pellucid and slender body, dorsally positioned eyes, and a scaleless venter, allow *E. vitreum* to inhabit such an environment (Winn and Picciolo, 1960). Unique among percid species, *E. vitreum* exhibits communal spawning (Winn and Picciolo, 1960).

Fisheries surveys conducted for the 1991 Maryland Doser Project resulted in the collection of *E. vitreum* from Faulkner Branch and Tull Branch (Marshyhope Creek drainage) on the Delmarva peninsula (Hall et al., 1992). The objective of this study was to document the current distribution of *E. vitreum* within Maryland's coastal plain streams.

### METHODS

Stream sample sites were selected following a review of the Maryland Synoptic Stream Chemistry Survey (Knapp et al., 1988) and specific topographical maps. Sites with historical populations of *E. vitreum*, such as Western Branch (Mansueti, 1950; Tsai and Golembiewski, 1979), Little Patuxent River at Conoways (Mansueti, 1950; Tsai and Golembiewski, 1979), and Patuxent River at Brock Bridge Road (Tsai and Golembiewski, 1979) were also included in the survey.

Backpack electrofishers (Smith-Root Model 15A; Coffelt Model Mark 10) were used to sample potential darter habitat. Depending upon stream width and habitat complexity, survey sites ranged in length between 25 and 100 m. Water temperature, conductivity, pH and dissolved oxygen were measured at all sample locations with portable field instruments. In addition, 125 ml water samples were collected for turbidity and acid neutralizing capacity (ANC) measurements.

### RESULTS AND DISCUSSION

A total of 30 streams were surveyed between 1 May and 1 July 1991 (Table 1). *Etheostoma vitreum* was collected from the following streams: Faulkner Branch, Tull Branch, Houston Branch, Sullivan Branch, two locations in Marshyhope Creek, and two locations in the Little Patuxent River. The identity of specimens collected from Faulkner Branch (Caroline County) and Little Patuxent River (Anne Arundel County) were verified by Larry Page (Illinois Natural History Survey). Five streams inhabited by *E. vitreum* were within the Marshyhope Creek/Nanticoke River drainage basin, which is located on the Delmarva peninsula. *Etheostoma vitreum* was not collected during previous fisheries surveys conducted in Maryland streams on the Delmarva Peninsula (Speir et al., 1976). The single western shore stream inhabited by this darter was the Little Patuxent River.

A size range of 22 to 76 mm standard length was recorded for all darters collected. Lee et al. (1980) reported an adult size range between 39 and 55 mm standard length. Although we did not age any of the darters, the smaller fish may indicate successful reproduction and recruitment.

No published information was available for suitable water quality parameters for *E. vitreum*. During this survey, *E. vitreum* was only collected from streams with pH greater than 6.5, acid neutralization capacity greater than 250  $\mu\text{eq/L}$ , conductivity greater than 65  $\mu\text{s/cm}$ , and baseflow turbidity less than 15 NTU (Table 2). It was also our observation that *E. vitreum* was only collected from waters less than 0.5 m in depth.

*Etheostoma vitreum* was only collected from one historical collection site on Maryland's western shore (Little Patuxent River). Tsai and Golembiewski (1979) stated that *E. vitreum* populations, which were common in 1966 and 1967, became very rare throughout the Patuxent River drainage basin in 1977. Although our collections of *E. vitreum* from the Delmarva peninsula indicate a range extension

TABLE 1. Maryland coastal plain streams sampled and number (N) of *Etheostoma vitreum* collected during 1991.

Stream	Drainage Basin	Historical Site	1991 Sites	N
Cecil County Bynum Run	Bush River		1	0
Kent County Mill Creek	Worton Creek		1	0
Queen Anne's County Unicorn Branch Red Lion Branch	Chester River Chester River		1 3	0 0
Caroline County Gravelly Branch Chapel Branch Houston Branch Sullivan Branch Twifford Meadow Ditch Tull Branch Faulkner Branch Marshyhope Creek	Choptank River Choptank River Marshyhope Creek 'Marshyhope Creek Marshyhope Creek Marshyhope Creek Marshyhope Creek Nanticoke River		1 1 1 1 1 2 3 2	0 0 7 1 0 3 18 21
Dorchester County North Davis Millpond Skimmers Run North Tara Branch	Marshyhope Creek Marshyhope Creek Marshyhope Creek		2 1 1	0 0 0
Wicomico County Rewastico Creek	Nanticoke River		1	0
St. Mary's County McIntosh Run	Potomac River		1	0
Charles County Rock Creek-Spice Run Mattaponi Creek Mattawoman Creek	Patuxent River Patuxent River Potomac River		1 1 2	0 0 0
Prince George's County Patuxent River Anacostia River Northeast Branch Western Branch	Chesapeake Bay Potomac River Anacostia River Patuxent River	X	1 1 1 1	0 0 0 0
Anne Arundel County Lyons Creek Stocketts Run Little Patuxent River Severn Run Bacon Ridge Branch North River	Patuxent River Patuxent River Patuxent River Chesapeake Bay South River South River	X	2 1 2 1 2 2	0 0 10 0 0 0

TABLE 2. Water quality parameters measured in streams sampled for *Etheostoma vitreum* during 1991 (nc = not collected).

Stream	Temp C°	pH	Cond μs/cm	DO mg/L	Turb NTU	ANC μeq/L
Bynum Run	nc	nc	nc	nc	nc	nc
Mill Creek	19.0	6.20	90	8.4	40.0	256
Unicorn Branch	22.5	7.13	149	9.6	3.5	476
Red Lion Branch - 1	23.0	7.13	139	6.2	nc	nc
Red Lion Branch - 2	22.8	7.03	140	6.7	nc	nc
Red Lion Branch - 3	22.2	7.04	110	7.2	nc	nc
Gravelly Branch	18.2	7.16	121	8.7	17.1	439
Chapel Branch	22.0	6.54	100	7.4	7.3	nc
Houston Branch	24.0	6.57	67	6.7	11.0	302
Sullivan Branch	21.1	6.57	130	6.7	7.0	551
Twifford Meadow	18.6	6.48	45	6.6	23.0	176
Tull Branch - 1	17.5	6.68	145	7.2	5.0	nc
Tull Branch - 2	15.0	6.70	132	7.8	11.0	nc
Faulkner Branch - 1	18.8	6.80	161	7.4	4.2	nc
Faulkner Branch - 2	16.0	6.77	149	7.6	8.0	290
Faulkner Branch - 3	21.0	6.88	130	6.5	6.0	nc
Marshyhope Creek	25.5	6.58	109	6.5	7.0	321
North Davis	22.1	6.12	122	7.0	nc	215
Skinners Run	18.5	6.25	155	8.6	4.0	220
North Tara Branch	16.5	6.33	52	7.9	6.0	84
Rewastico Creek	23.0	6.28	118	4.6	11.0	nc
McIntosh Run	23.1	7.11	119	6.5	13.0	727
Rock Creek	20.5	6.14	110	7.0	13.5	308
Mattaponi Creek	21.0	6.68	220	6.5	14.5	274
Mattawoman Creek - 1	17.0	nc	70	7.8	29.0	nc
Patuxent River	nc	nc	nc	nc	nc	nc
Anacostia River	nc	nc	nc	nc	nc	nc
Northeast Branch	nc	nc	nc	nc	nc	nc
Western Branch	22.0	7.23	208	5.7	20.8	1066
Lyons Creek - 1	19.9	nc	165	7.2	43.0	460
Lyons Creek - 2	21.0	7.14	150	7.8	25.0	308
Stocketts Run	18.5	7.04	148	9.1	8.5	489
Little Patuxent	19.0	7.05	313	7.0	9.5	1468
Severn Run	24.0	6.33	108	6.0	6.5	nc
Bacon Ridge Branch-1	17.3	7.03	100	8.4	13.0	nc
Bacon Ridge Branch-2	19.0	7.04	100	8.6	11.0	nc
North River	19.1	6.47	80	7.8	11.0	nc

for this species within Maryland (Speir et al., 1976; Lee et al., 1980), it is most likely that this species has existed on the Delmarva peninsula but was either not collected or incorrectly identified. The site at Western Branch, which contained a significant population of *E. vitreum* during the 1950's (Winn and Picciolo, 1960), has been dramatically altered. The U.S. Geologic Survey weir was removed in 1975 and currently the substrate is laden with silt. The Patuxent River site also has been impacted from anthropogenic sources (e.g., silt, illegal dumping). This recent discovery and extended range for *E. vitreum* merits consideration for a change in status of this species, which is presently classified as an endangered extirpated species within Maryland. The future existence of this darter species in Maryland is dependent upon a stable and protected environment. Increasing population growth and resulting changes in land-use activities (e.g., increased urban development and loss of forest and agricultural land), agricultural practices, stream maintenance projects (e.g., channelization, sediment traps), and the impacts of beaver impoundments need to be closely monitored to avoid adverse impacts on *E. vitreum* habitat.

#### ACKNOWLEDGEMENTS

S.A. Fischer (Research Assistant) was the field supervisor; L.W. Hall, Jr. (Principal Investigator) was project supervisor; W.D. Killen, Jr. (Technician) assisted with the data collection. This study was sponsored by the Maryland Department of Natural Resources (MDNR; Contract number CB91-003-002). We are grateful to Paul Miller (MDNR) and Ronald J. Klauda (MDNR) for their contributions to the study design. John Cooper, Nick Carter, and Ray Morgan are acknowledged for their insight and comments.

#### LITERATURE CITED

- Hall, L.W., Jr., S.A. Fischer, W.D. Killen, Jr., M.C. Ziegenfuss, and R.D. Anderson. 1992. 1991 Maryland Doser Study in Maryland Coastal Plain Streams: Use of Lime Doseers to Mitigate Stream Acidification. Maryland Dept. Nat. Resour., Chesapeake Bay Res. Monit., Annapolis.
- Knapp, C.M., W.P. Saunders, Jr., D.G. Heimbuch, H.S. Greening, and G.J. Filbin. 1988. Maryland Synoptic Stream Chemistry Survey: Estimating the Number and Distribution of Streams affected by or at Risk from Acidification. Maryland Dept. Nat. Resour., Power Plant Res. Prog., Annapolis.
- Lee, D.S., R.E. Jenkins, and C.R. Gilbert. 1980. *Etheostoma vitreum* (Cope), glassy darter, p. 708. In: Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister and J.R. Stauffer, Jr. Atlas of North American Freshwater Fishes. N. C. State Mus. Nat. Hist., Raleigh.
- Mansueti, R. 1950. An Ecological and Distributional Study of the Fishes of the Patuxent River Watershed, Maryland. M.S. thesis. University of Maryland, College Park, MD.
- Maryland Dept. of Natural Resources (MDNR). 1991. Rare, Threatened, and Endangered Animals of Maryland. Maryland Nat. Heritage Prog., Dept. of Nat. Resour., Annapolis.
- Speir, H.J., D.R. Weinrich, and W.R. Carter, III. 1976. Evaluation of the Effects of Channelization on Small Coastal Plain Streams of Maryland. Maryland Dept. Nat. Resour. Rep. F-24-R. Annapolis, MD.

- Tsai, C. and S.L. Golembiewski. 1979. Changes in Fish Communities in the Upper Patuxent River from 1966 to 1977. Maryland Dept. Nat. Resour., Annapolis.
- Winn, H.E. and A.R. Picciolo. 1960. Communal Spawning of the Glassy Darter *Etheostoma vitreum* (Cope). Copeia 1960(3):186-192.

**VIRGINIA ACADEMY OF SCIENCE**  
**Council Meeting Minutes**

November 17, 1991, University of Virginia

Present: Gerald Taylor, Jr. (President), Richard Brandt (Immediate Past President), Michael Bass (Past-Past President), Golde Holtzman (President-Elect, Chair 1991 LAC), Carolyn Conway (Secretary, Chair Business and Policy Review Comm.), Blanton Bruner (Executive Secretary-Treasurer), Dean Decker (Director VJAS, Chair VJAS Comm., Chair 1992 LAC), Jim Martin (Editor/Business Manager VJS), James O'Brien (Editor Virginia Scientist, Chair Publications Comm., Co-chair Psychology), Ertle Thompson (AAAS Representative, Chair Search Committee for VJAS Director), Vera Remsburg (Science Museum of VA Trustee), Martha Roane (Chair Archives Comm.), Elsa Falls (Co-chair Awards Comm.), Art Burke (Chair Finance Comm.), Rae Carpenter (Chair Trust Comm., Chair Futures Comm.), Harold Bell (Director Visiting Scientist Program), Carvel Blair (Chair Committee on Environment, Councilor Environmental Sciences), Scott Newton (Councilor Agriculture, Forestry, & Aquaculture), Michael Barder (Councilor Archaeology), Rosemary Barra (Councilor Biology), Greg Cook (Secretary & Councilor Computer Science), Donald Ramirez (Councilor Statistics)

The meeting was called to order at 1:08 p.m. by President Gerald Taylor. Those present introduced themselves.

Approval of Council Minutes of May 22 and 24, 1991

1. The minutes of the May 22 Council Meeting at VPI were approved as distributed, as moved by Michael Bass and seconded by Richard Brandt.
2. The minutes of the May 24 Council Meeting at VPI were approved as corrected, as moved by Golde Holtzman and seconded by Martha Roane.

President's Report - Gerald Taylor.

Dr. Taylor's report (attached) included the following information:

1. The 1991-1992 VAS Directory has been published (with much help from Jim Martin) as a supplement to Volume 42 of the VA Journal of Science. Martha Roane pointed out some omissions in the directory. Other omissions should be sent to James O'Brien by January 1 for inclusion in the Virginia Scientist.
2. Vera Remsburg has been reappointed to another term on the Board of Trustees of the Science Museum of Virginia.
3. There is a need to continue to increase VAS membership, especially business members.
4. Dr. Taylor received a written request to establish a Geography Section of VAS. Everyone present was in agreement that Council should encourage the development of the Geography section and allow the group to meet at the 1992 VAS meeting at UR. James O'Brien moved that we encourage the

formation of a Geography section within the VAS. Martha Roane seconded. The motion was approved unanimously. Dr. Taylor has asked Stephen Wright from JMU to act as interim secretary and Council representative.

5. As part of his written report, Dr. Taylor distributed copies of the charge to the Futures Committee and the charge to the Search Committee: Interim Director of VJAS. These charges were presented to the respective committees in May 1991 and these Committees have been busy since that time.
6. Dr. Taylor summarized the activities and Executive Committee recommendations related to the search for a new VJAS Director. Since the appointment in May 1991 of the Search Committee (with Ertle Thompson as Chair and Dean Decker as a member), a number of important events and meetings have transpired. At a special meeting (July 20, 1991, at Graves Mountain Lodge), the Executive Committee approved, in concept, a proposal from the VAS to the Science Museum of Virginia to establish a VJAS Director/Science Education Liaison position with offices and staff support in the Science Museum of Virginia. The concept behind this position had been previously approved by the Science Museum of Virginia. This would be a paid position (State funding through the Science Museum of Virginia) with a good chance of being funded. Discussion related to this new position followed. One important question raised was whether the new VJAS Director should be a voting member of the Executive Committee.

VAS-Future's Committee Report - Rae Carpenter.

1. Copies of the report from the Future's Committee (attached) were distributed. In his report, Dr. Carpenter outlined the tentative plans for the VJAS Director/Science Liaison position and for the eventual relocation of VAS offices to the Science Museum of Virginia. Definitive information related to the funding for the VJAS Director/Science Liaison position will not be available until January 1992 when the Governor's budget is announced. If the position is funded, then VAS will proceed with plans as proposed. If the position is not funded, VAS will still hire a VJAS Director but the position will continue to be a volunteer one.
2. Dr. Carpenter, on behalf of the Futures Committee, moved that the summary (as distributed) containing the major elements relating to the move of the VAS offices to the Science Museum of Virginia be approved subject to the Museum's obtaining the necessary State funding for the biennium beginning July 1, 1992. The motion was seconded by Michael Bass. A lengthy discussion followed. During the discussion period Golde Holtzman emphasized that the intent of the motion was to obtain Council's approval of the plan without indicating that the plan must be executed. The motion was approved unanimously.
3. Dr. Carpenter, again on behalf of the Futures Committee, moved that Council name Dean Decker as the VJAS Interim Liaison to attend Council meetings for 1992 and 1993 with privileges of the floor. During the discussion that

followed, questions were raised, and comments made, concerning the voting privileges of the new VJAS Director. The motion was approved unanimously.

Search Committee (Interim Director of VJAS) Report - Ertle Thompson.

1. Copies of the report of the Search Committee (attached) were distributed. Dr. Thompson's report included historical documentation of the discussions and activities related to the proposed search for a new Director of VJAS and the proposal from the Science Museum of Virginia for the joint VJAS Director/Science Liaison position. Note for clarification: In the Search Committee Report this position is referred to as the SMV/VAS "Scientist in Residence" and Director VJAS at the SMV and in the attached communications from the SMV this position is referred to as the Science Outreach Program Coordinator.
2. Dr. Thompson, on behalf of the Search Committee, recommended/moved that Council approve, in concept, the joint position of SMV/VAS "Scientist in Residence" half-time and Director of VJAS half-time at the Science Museum of Virginia. The motion was seconded by Art Burke. During the discussion Dr. Thompson indicated that if the position is funded the expectations (of SMV staff) are that the position would be filled by a Ph. D. (or equivalent) scientist or mathematician. The motion was approved unanimously.
3. Dr. Thompson, again on behalf of the Search Committee, recommended/moved that the search for the Director VJAS (volunteer-unpaid) be aggressively pursued, so that potential candidates may be recommended to the Executive Committee in March, should the funding of the position at the Science Museum of Virginia not be approved in the State budget process. The motion was approved unanimously.

Comments by Director, Virginia Junior Academy of Science - Dean Decker.

Dean commented that the VJAS is one of most important things that VAS does especially in reference to related activities at the national level. Dean pointed out that in some states Junior Academy of Science activities do not include paper presentations on research activities.

**OFFICER'S REPORTS**

President Elect - Golde Holtzman.

1. As Chairman of the LAC for 1991 meeting at VPI, Dr. Holtzman reported that the meeting operated "in the black". Meeting statistics were: 793 VJAS registrants, 483 VAS registrants, 24 registered exhibitors; 50 VAS registrants and approximately 800 VJAS registrants attended the picnic; 128 VAS registrants and/or guests attended the banquet. A detailed report from the 1991 LAC was submitted to the Executive Committee and is available for examination by interested persons.

2. With respect to the 1992 meeting at UR, the Schedule of Responsibilities will be sent out in December.
3. A potential speaker (to be announced later) has been invited for the Negus lecture.

Secretary. No report.

Treasurer. No report.

Executive Secretary-Treasurer - Blanton Bruner.

Mr. Bruner reported that the 1992 dues statements have been sent out. A number of VAS members have already returned their statements with payment.

Immediate Past President - Richard Brandt

The Virginia Division of the American Cancer Society will be contributing \$1000 to be used for VJAS awards at the UR meeting. The necessary details will be worked out by Dr. Decker and Dr. Brandt.

Past-Past President. No report.

Past-Past-Past President. No report.

**LOCAL ARRANGEMENTS COMMITTEES, DIRECTORS, AND  
REPRESENTATIVES REPORTS**

1992 Local Arrangement Committee - Dean Decker.

The plans for the UR meeting are well under way. Some events have already been scheduled. The President's Reception will be held in the Lora Robins Gallery. Details concerning prices, menus, etc., will probably be worked out prior to the January VJAS Committee meeting.

Director of Virginia Junior Academy of Science - Dean Decker.

Announcements concerning VJAS activities, including paper deadlines, have been sent out. The VJAS Vice President is being relocated. Plans are being made for representatives to attend the American Junior Academy of Science meeting. The speaker for the 1st George Jeffers Lecture will be Dr. Debra Malloy Elmegreen (VJAS President in 1971), an astronomer, from Vassar.

Editor and Manager of VA Journal of Science - Jim Martin.

As indicated earlier, the VAS Directory was a supplement to the VA Journal of Science. Copy for the next two issues of the journal is set.

Editor of VA Scientist - James O'Brien.

Dr. O'Brien asked for feedback concerning the length of the newsletter. Gerald Taylor indicated the need to establish a budget to cover costs of

production and mailing. Additional discussion concerned the mailing of the newsletter to non-academy members and the excellent publicity that the newsletter provides for VAS. Currently the newsletter is sent to 15-20 State departments and the Governor's office, to members of the VJAS Committee, and to the presidents of all public and private colleges/universities in the state (with the exception of those that are exclusively religious or business). Art Burke moved that the VA Scientist be sent to all State legislators. Michael Bass seconded. The motion passed unanimously.

Director of Visiting Scientists Program - Harold Bell.

The new program booklet was distributed to high schools and a number of middle schools at the beginning of the 1991-1992 school year. Approximately 250 booklets were taken by Dr. Thompson to the recent Science Teachers Meeting. Several booklets were available for pickup by interested Council members.

AAAS Representative. No report.

Science Museum of Virginia Trustee. No report.

**STANDING COMMITTEE REPORTS**

Archives Committee - Martha Roane.

A box of information from the May 1991 meeting was received from Vera Remsburg and passed on to the appropriate individuals at VPI. Howard Davis is working on a history of the VJAS and is interested in material in the Archives. Martha reminded Council members to send any archival material to her or Glenn McMullen who is the official archivist.

Awards Committee - Elsa Falls.

This committee is responsible for receiving and/or making nominations for various awards (i.e., Ivey F. Lewis Distinguished Service Awards, special awards, Fellows). Several Council members suggested that the University of Richmond might be honored in commemoration of their long standing association with VAS/VJAS.

Constitution and Bylaws Committee. No report.

Finance and Endowment Committee - Art Burke.

1. The proposed budget for 1992 (attached) was presented. Dr. Burke, on behalf of the Finance Committee, moved that the 1992 proposed budget be approved. Rae Carpenter seconded the motion. Questions raised about various line items were discussed. Dr. Taylor pointed out that \$300/year of the President's Discretionary Fund is appropriated for the SMV Trustee. The proposed budget, as presented, was approved unanimously.
2. Dr. Burke presented, for information only, a supplementary budget request (attached) which had been proposed by President Taylor and submitted to

the Executive Secretary-Treasurer and to the Finance and Endowment Committee. This request included the proposed income and disbursements, for the period April through June 1992, related to the proposed VJAS Director/Science Liaison position at the SMV.

Fund Raising Committee. No report.

Junior Academy of Science Committee. No report.

Long-Range Planning Committee - Richard Brandt.

Sites, as well as LAC Chairmen, for the Annual Meeting are set through 1995.

Membership Committee - Richard Brandt for Hugo Seibel.

As requested, letters were sent to all State agencies in an attempt to identify persons interested in joining VAS. No replies were received. Every Council Member was asked to get one new member. It was suggested that students be given memberships as gifts.

Nominations and Elections Committee. No report.

Publications Committee. No report.

Research Committee. No report.

Science Advisory Committee - Richard Brandt for William Dewey.

Dr. Dewey will submit within the month a committee recommendation for members to be added to this committee. These individuals will have to be members of the VAS.

Science Education Committee.

There was no official report. Dr. Burke reported that the Fall Science Teacher's Conference and Workshop in Norfolk was very successful.

Trust Committee - Rae Carpenter.

Copies of the report (attached) were distributed and explanatory information was provided. VAS is in good financial health. Dr. Carpenter noted that Hugo Siebel's name was inadvertently omitted from the list of committee members.

Virginia Flora Committee. No report.

#### OTHER COMMITTEE REPORTS

Committee on Environment - Carvel Blair.

Prior to Dr. Blair's report, Dr. Taylor reminded Council that (as approved at the May 24, 1991, Council meeting) the appropriate plans should be initiated

to establish this as a Standing Committee. The appropriate paperwork (to initiate a change in the Bylaws and to establish the committee charges) should be brought before Council at the March 1992 meeting. The official vote on the Bylaw change will occur at the May 1992 meeting.

Dr. Blair reported on several environmental issues being reviewed by this committee. A genetically engineered rabies vaccine for wild raccoons was tested last year on Paramore Island. This committee will handle the review of the reports from this study. Another topic to be considered is a controversy concerning the mining of gravel from riverbeds.

Committee on Policies and Business Review. No report.

#### SECTION REPORTS

Aeronautical and Aerospace Section. No report.

Agriculture, Forestry & Aquaculture Section - Scott Newton.

Members of this section anticipate having one or more paper sessions at the 1992 meeting.

Archaeology Section - Michael Barber.

More papers are planned for the 1992 meeting.

Astronomy, Mathematics & Physics Section. No report.

Biology Section. No report.

Biomedical & General Engineering Section. No report.

Botany Section. No report.

Chemistry Section. No report.

Computer Science Section - Greg Cook.

President's discretionary funds were used for the production of posters to notify interested individuals of the newly established section and the Annual meeting.

Education Section. No report.

Environmental Sciences Section - Carvel Blair.

Dr. Blair would like to have papers on the rabies vaccine and riverbed mining submitted for the 1992 meeting.

Materials Science Section. No report.

Medical Sciences Section. No report.

Microbiology and Molecular Biology Section. No report.

Psychology Section - James O'Brien.

Dr. O'Brien expressed appreciation to the Department of Psychology at VPI for providing refreshments for this section at the 1991 meeting.

Statistics Section - Golde Holtzman for Donald Ramirez.

Dr. Holtzman reported that section activities are going well.

### OTHER OLD BUSINESS

Rae Carpenter, having consulted the Bylaws, informed President Taylor that Council needed to elect Hugo Seibel to membership on the Trust Committee. James O'Brien moved that Council elect Hugo Seibel to the Trust Committee for the term 1991-1994. Elsa Falls seconded the motion. The motion passed unanimously.

### NEW BUSINESS

1. Rae Carpenter indicated that it was time for Council to consider commissioning a new VAS history specifically for the period of 1965 through 1990. Various Council members suggested that the President appoint an Ad Hoc Committee to consider this. Martha Roane, as Archives Committee Chair, volunteered to explore this and to report to Council at the March meeting.
2. Golde Holtzman informed Council of the production by the VPI Departments of Statistics and Computer Science (along with the American Statistical Association and the Association of Computing Machinery) of 2 videotapes about I. J. Good (University Distinguished Professor of Statistics and a past VAS member and former Horsley Award winner), Donald Michie, and David Kahn. VAS, through a donation, can become a sponsor in this endeavor and receive some publicity. Michael Bass moved that VAS be a partner and sponsor by contributing \$500. Dean Decker seconded the motion. The motion passed unanimously.

Announcements.

Prior to adjournment Vera Remsburg thanked Gerald Taylor for his effective leadership and direction of the Academy.

President Taylor adjourned the meeting at 4:48 p.m.

Respectfully submitted by:  
Carolyn M. Conway, Secretary  
Virginia Academy of Science

**SUMMARY OF MOTIONS  
COUNCIL MEETING, NOVEMBER 17, 1991**

1. That the minutes of the May 22 meeting be approved as distributed. Moved by Michael Bass and seconded by Richard Brandt. Motion passed unanimously.
2. That the minutes of the May 24 meeting be approved as corrected. Moved by Golde Holtzman and seconded by Martha Roane. Motion passed unanimously.
3. That Council encourage the formation of a Geography section within the VAS. Moved by James O'Brien and seconded by Martha Roane. Motion passed unanimously.
4. That the summary (as contained in the Futures Committee Report) containing the major elements relating to the move of the VAS offices to the Science Museum of Virginia be approved subject to the Museum's obtaining the necessary State funding for the biennium beginning July 1, 1992. Moved by Rae Carpenter for the Futures Committee and seconded by Michael Bass. Motion passed unanimously.
5. That Council name Dean Decker as the VJAS Interim Liaison to attend Council meetings for 1992 and 1993 with privileges of the floor. Moved by Rae Carpenter for the Futures Committee. Motion passed unanimously.
6. That Council approve, in concept, the joint position of SMV/VAS "Scientist in Residence" half-time and Director of VJAS half-time at the Science Museum of Virginia. Moved by Ertle Thompson for the Search Committee (Interim Director of VJAS) and seconded by Art Burke. Motion passed unanimously.
7. That the search for the Director VJAS (volunteer-unpaid) be aggressively pursued, so that potential candidates may be recommended to the Executive Committee in March, should the funding of the position at the Science Museum of Virginia not be approved in the State budget process. Moved by Ertle Thompson for the Search Committee (Interim Director of VJAS). Motion passed unanimously.
8. That the VA Scientist be sent to all State legislators. Moved by Art Burke and seconded by Michael Bass. Motion passed unanimously.
9. That the 1992 proposed budget be approved. Moved by Art Burke for the Finance Committee and seconded by Rae Carpenter. Motion passed unanimously.

10. That Council elect Hugo Seibel to membership on the Trust Committee.  
Moved by James O'Brien and seconded by Elsa Falls. Motion passed unanimously.
11. That VAS be a partner in, and sponsor of, the production of videotapes about Drs. Good, Michie, and Kahn by contributing \$500. Moved by Michael Bass and seconded by Dean Decker. Motion passed unanimously.

## VIRGINIA ACADEMY OF SCIENCE EXECUTIVE COMMITTEE MINUTES

November 17, 1991, University of Virginia

Present: Gerald Taylor, Jr. (President), Richard Brandt (Immediate Past President), Michael Bass (Past-Past President), Golde Holtzman (President-Elect), Carolyn Conway (Secretary), Blanton Bruner (Executive Secretary-Treasurer), Dean Decker (Director VJAS), Jim Martin (Editor/Business Manager VJS), Art Burke (Chair Finance Committee), Ertle Thompson (Chair Search Committee for VJAS Director)

The meeting was called to order at 10:10 a.m. by President Gerald Taylor.

### Approval of Executive Committee Minutes.

1. The minutes of the Executive Committee Meeting of May 22, 1991, were approved as distributed, as moved by Michael Bass and seconded by Dean Decker.
2. The minutes of the Executive Committee Meeting of May 24, 1991, were approved as corrected, as moved by Michael Bass and seconded by Dean Decker.
3. The minutes of the special Executive Committee Meeting held at Graves Mountain Lodge on July 20, 1991, were approved as distributed, as moved by Michael Bass and seconded by Dean Decker.

President's Report - Gerald Taylor. Dr. Taylor's report (attached), part of which he will be giving at the Council meeting, included the following information:

1. The 1991-1992 VAS Directory has been published as a supplement to the VA Journal of Science.
2. Vera Remsburg has been reappointed to another term on the Board of Trustees of the Science Museum of Virginia.
3. There is a need to increase membership in VAS, especially business members.
4. Dr. Taylor has received a written request to establish a Geography section. Council will be asked to allow the group to hold its first paper session and business meeting at the 1992 VAS meeting. Formal admission of the group into VAS would occur at the 1992 meeting. Discussion followed. Everyone present was in agreement with the request to establish this new section.
5. As part of his written report, Dr. Taylor distributed copies of the charges (given at the 1991 meeting) to the Futures Committee and to the Search Committee: Interim Director of VJAS.
6. Dr. Taylor summarized the status of the search for VJAS Director. Plans are underway to search for a VJAS Director/Science Museum of Virginia Education Liaison. The position has been approved, in concept, by both the VAS and the SMV. The availability of funds for this joint position is uncertain at this time. Dean Decker will be asked to serve as the VAS

Council's VJAS-Interim Liaison next year. In the event that funding is not available from the state for the joint position, VAS will search for a volunteer director.

7. **VAS Office Location.** Some considerations and plans should be made to prepare for the potential move of VAS offices. Discussion followed. More information related to this matter should be available at the March Council meeting.
8. A number of personnel matters (which would not be brought up during the Council meeting) were discussed at length. An assistant for the Executive Secretary-Treasurer should be named soon so that he can work with Blanton Bruner. There is a volunteer, who is a Past President of the VAS. Michael Bass moved that an assistant for the Executive Secretary Treasurer be appointed for a period of 5 years to assist Mr. Bruner. Dean Decker seconded the motion. In the discussion that followed it was suggested that details be worked out and presented at the March 1992 Council meeting. The motion passed unanimously. Additional discussion related to other personnel matters and activities that occur in and outside the VAS office at UR.

President Elect's Report - Golde Holtzman.

1. Dr. Holtzman began by thanking Dr. Taylor for his work on the VAS Directory and for being a very active President.
2. As Chairman of the LAC for the 1991 meeting, Dr. Holtzman passed out the Table of Contents (attached) from the very extensive final report and associated budget/financial information (attached). Various aspects of the budgetary information were discussed. Dr. Holtzman pointed out the need for a deposit from the students or from their schools to cover damage costs. He indicated the exhibits were poorly attended especially by those attending VJAS.
3. 1992 Negus Lecture. The first choice for a speaker for the Negus lecture is Peter Raven, from the Missouri Botanical Gardens, who would speak on an environmental topic. The alternative is Lester Brown, Director of World Watch. During the discussion concerning the Negus lecture, Dr. Taylor pointed out that it is the President's responsibility to actually invite the Negus lecturer. As has been the custom over the past few years, the President-Elect has been asked to find a suitable speaker. There was some discussion concerning the amount of the honorarium for the Negus lecture and the possibility of increasing the honorarium was presented.
4. Other Plans for 1992 meeting. Dr. Holtzman presented the time line for the UR meeting. There was some discussion concerning the timing of the Call for Papers. The LAC will meet at UR on Friday, Jan. 17, 1992 (the day preceding the January VJAS Committee meeting).

Secretary's Report. No report.

Treasurer's Report. No report.

Past-President's Report - Richard Brandt.

The Virginia Division of the American Cancer Society will contribute \$1000 to VJAS for awards for the 1992 meeting.

VJAS Director's Report - Dean Decker.

Dr. Decker informed the Executive Committee of the passing of Eleanor Tenney. He asked whether VAS wanted to do something in her memory. All present agreed that she should be considered for a Distinguished Service Award.

New Business.

1. Dr. Holtzman explained about several videotapes that are being prepared about Dr. I. J. Good (a former Horsley Award winner) and several of his colleagues. Donations are needed to help pay for the development of these videotapes. Michael Bass moved that VAS contribute \$500 toward this endeavor. Art Burke seconded. The motion passed unanimously.
2. Dean Decker reported that the local arrangements for the 1992 meeting at UR are proceeding according to schedule.

The meeting was adjourned at 12:06 p.m.

Respectfully submitted by:

Carolyn M. Conway, Secretary  
Virginia Academy of Science

SUMMARY OF MOTIONS  
EXECUTIVE COMMITTEE MEETING, NOVEMBER 17, 1991

1. That an assistant to work with the Executive Secretary Treasurer be appointed for a period of 5 years to assist Mr. Bruner. Moved by Michael Bass and seconded by Dean Decker. Motion passed unanimously.
2. That VAS contribute \$500 toward the development of videotapes about Dr. I. J. Good and his professional colleagues. Moved by Michael Bass and seconded by Art Burke. Motion passed unanimously.



### **Franklin Ford Flint 1925-1992**

Dr. Franklin F. Flint died on January 13, 1992, as a result of injuries suffered in an automobile accident. He retired in July 1991 from Randolph-Macon Woman's College where he was the Charles A. Dana Professor of Biology.

Dr. Flint was born in 1925 in Lunenburg County, Virginia. He received his Bachelor's degree from Lynchburg College and his Master's and Doctorate from the University of Virginia. He joined the Navy in 1943 and served in the European and Pacific Theaters in World War II and upon his discharge joined the Naval Reserve Intelligence Unit where he obtained the rank of commander.

In 1957-58 he conducted post-doctoral research in California and in 1968-69 was a Senior Fulbright-Hayes Research Fellow at Oeiras, Portugal. He was Staff Biologist with CUEBS in 1968-69 and an Extramural Associate with NIH in 1981. He was the author of numerous scholarly papers in the area of biological science and education.

Dr. Flint served the Virginia Academy as Chief Judge of the Junior Academy, Chairman of the Biology Section and Secretary and President in 1972-73. He was elected a Fellow of the VAS in 1973 and was Vice-President of the Science Museum of Virginia Foundation, Inc. in 1975-76. He had served as President of the Association of Southeastern Biologists, the Conservation Council of Virginia and the Virginia Association of Soil and Water Conservation Districts. He was granted the Thornton Award from Lynchburg College in 1985. Currently, he was on the National Board of Directors of the Izaak Walton League of America and President of its Virginia Division.

He was an esteemed and dedicated faculty member at Randolph-Macon Woman's College where he served 40 years in the Biology Department, with 24 years as chairman. In 1979 he received the Davidson Award for distinguished faculty service.

He was Chief Marshal of R-M.W.C. 1983-91.

He was the recipient of conservation awards from the Robert E. Lee Soil and Water Conservation District and the Virginia Division of the Izaak Walton League. He was named "Soil Conservationist of the Year", Governor's Trophy Award in 1977 by the Virginia Wildlife Federation. He recently received the Rosette as a Fellow of the AAAS for his service and distinction in science.

As a leader in many local conservation and service organizations, Dr. Flint projected a sense of responsibility. He was a past president of the Friends of Lynchburg Stream Valleys and served on the Keep Lynchburg Beautiful Commission and on the Steering Committee for the master planning and development of the Blackwater Creek Natural Area which is a lasting memorial to him and his service to the community.

Scholar, conservationist, teacher; perhaps the latter was dearest to his heart. Students knew they had a friend the moment Frank walked into the classroom with his cheerful greeting. His interesting lectures were sprinkled with anecdotes and subtle humor. Many students have been inspired by his enjoyment of teaching and his deep interest and concern for them as individuals. In 1972 he developed a course entitled Conservation of Natural Resources which sparked the interest of his students in the environment and in biology. Many of them have gone on to graduate school and have achieved eminence in the field of science.

He is survived by his widow, Dona Cook Flint, two daughters, Kathryn Flint Garrett and Julie Flint Francis, a son, Roger Franklin Flint and three grandchildren.

With all of his many scientific accomplishments, his family still came first. In recent years Frank and Dona enjoyed a new dimension in their lives - the excitement and affection of their grandchildren.

All of us are extremely privileged to have known Dr. Flint and he continues to be an inspiration to those who have been touched by his life.

**Scientific Fraud:** Antonov, L.S., and G.H. Lacy. 1991. *Erwinia carotovora*: Fusions between *pelA* and *pelB* have pectolytic activity, Va. J. Sci. 42(2):244 (abstract).

Some of the data upon which this abstract was based was fabricated or knowingly incomplete. The responsible party was terminated as a candidate for the PhD degree. Specifically, evidence for activity of partial pectate lyases was based on falsified data and the 3'-terminal part of the *pelB* open reading frame may be incomplete or incorrect. I apologize to the members of the Virginia Academy of Science, readers of this journal, and attendees of the Sixty-ninth Annual Meeting of the Virginia Academy of Sciences held on 21-24 May, 1991 at Virginia Polytechnic Institute and State University for the publication of this fraudulent abstract.

George H. Lacy

## **NOTES**

## **NOTES**

## **NOTES**

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Spry, A. 1969. Metamorphic Textures. Pergamon Press, New York. 350 pp.

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### **EDITOR/BUSINESS MANAGER:**

**James H. Martin**  
Dept. of Biology - PRC  
J. Sargeant Reynolds Community College  
P.O. Box 85622  
Richmond, VA 23285-5622  
Phone: (804)371-3064

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# **Land Use Patterns and Impacts on the Biota of Virginia: Symposium Introduction**

**Ralph P. Eckerlin**, Natural Sciences Division

Northern Virginia Community College

Annandale, VA 22003 and

**Gerald E. Meier**, Weinberg Consulting Group Inc.

220 19th St. NW, Suite 300, Washington, D.C. 20036

On May 24, 1991, a symposium entitled "Land Use Patterns and Impacts on the Biota of Virginia" was held as a part of the 69th Annual Meeting of the Virginia Academy of Science. At this symposium, held at Virginia Polytechnic Institute and State University in Blacksburg, VA, 17 papers were presented dealing with a variety of factors which have influenced and continue to influence the biological component of Virginia.

Sponsored by the Biology section of the Academy, this symposium was well attended and, judging from the discussions that developed during that day, well received.

The following 12 papers represent the proceedings of this symposium. These papers address a range of factors that have influenced, and are influencing the biota of Virginia. Among these are geological events, evolutionary events, and ecological events. In any context, change, whether the result of natural or man influenced processes, continues to shape Virginia's biological communities. Our scientific community, our citizenry, and our lawmakers need to understand these processes of change and their consequences to the well-being of organisms and communities of organisms. This must occur before effective steps can be implemented to slow or reverse deleterious trends.

As the papers that follow in this proceeding will demonstrate, there is a distinct need to emphasize the preservation of habitat in addition to the preservation of species. Habitat preservation will, in general, protect and preserve the associated species. Failure to maintain acceptable habitats will certainly result in the loss of these same species. Wetlands preservation, though currently in a state of disarray because of changing regulatory definitions, represents a significant step toward maintaining suitable habitats. Other types of habitat deserve consideration as well.

We in Virginia are fortunate to have so many talented, dedicated and knowledgeable scientists who are interested in the environment. This proceedings gives an overview of some of the areas that are being studied. It is our belief that a decennial look at the environment and the effects of land use would be useful. This would parallel the once a decade report that is made on the endangered species of Virginia.

## **ACKNOWLEDGEMENTS**

The original concept of the symposium theme was proposed by Gerald E. Meier. All of the presenters at the symposium and particularly all of the authors are to be congratulated for doing a fine job. Numerous colleagues, who must remain anonymous, reviewed manuscripts and improved them with their suggestions. Natalie Reeves provided much assistance with word processing. Funds to support the symposium were provided by the Virginia Academy of Science.



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## Late Triassic Faunal Successions of Central Pangaea

Nicholas C. Fraser, Virginia Museum of Natural History,  
1001 Douglas Avenue, Martinsville, Virginia 24112.

### ABSTRACT

Mass extinctions have long been recognized in the fossil record. The end Permian extinction was by far the greatest of these, and the terminal Cretaceous extinction is well known for the demise of the dinosaurs. However the exact nature, timing and causes of such events are still disputed. Large scale global extinctions are known to have occurred at the end of the Triassic period. The Triassic period is a key period in the evolution of modern terrestrial vertebrates. Triassic sediments in Virginia are producing rich and varied faunas which are beginning to shed considerable light on global events at this time.

**Key Words:** Triassic, Carnian, Norian, Pangaea, Virginia, tetrapods, extinctions, Newark Supergroup.

### INTRODUCTION

Extinction is an integral part of macroevolution, and in some ways it can be viewed as a balancing effect on mechanisms of species origination. In recent years interest in extinctions has centered upon two aspects. 1) Man's ability to alter population numbers drastically in a very short period of time has generated increasing debate. 2) No less a controversial subject is the nature of extinctions throughout the history of life. In the case of the former we have difficulty assessing the impact of man over a relatively prolonged period of time since the database has only been accumulated over the last few decades. In the case of the latter the reverse is true: we know the effect over a long period of time, but we have difficulty in resolving the exact pattern and tempo of extinctions.

Major crises in the earth's biota are often viewed as a departure from the "normal" process of evolution. Yet mass extinctions, whilst decreasing diversity in the short term, may have operated to maintain the ecological diversity of life on a geologic time-scale. Initial analyses of global mass extinctions (and radiations) were at the stratigraphic level of stage and the taxonomic level of family (e.g. Sepkoski, 1982; Benton, 1985a), but such studies have proved too general to be able to resolve many of the more critical questions. There is a need for more detailed analyses using data at least at the regional, generic (and preferably species) and zonal levels.

The controversial proposal that a meteorite impact may have caused mass extinctions at the close of the Cretaceous period (Alvarez et al., 1980) produced a resurgence of interest in the demise of the dinosaurs. While the evidence for an impact is now very compelling, whether it was responsible for the sudden extinction of groups such as the dinosaurs is equivocal. Part of the dispute lies in the difficulty of dating sediments to within less than  $\pm$  1 million years, and then correlating these sediments to other areas worldwide. Assessing the nature, timing and causes of other so-called mass extinction events, such as the great end Permian extinction, are subject to the same problems. Likewise, although the proposal of Raup and Sepkoski (1984) that there is a 26 million year periodicity in mass extinctions has

received some support, once again the evidence is inconclusive when the inadequacy of the geological time scale is taken into account.

A mass extinction at the end of the Triassic has been recognized by many authors (Colbert, 1958; Newell, 1967; Hallam, 1981; Raup and Sepkoski, 1982) although it is not widely cited in the popular literature because it does not mark the disappearance of any well known group. Recent work by Olsen and colleagues (Olsen et al., 1978; Olsen, 1986, 1988; Olsen et al., 1987) on Triassic - Jurassic deposits of eastern North America strongly suggest that very fine temporal control is provided by sedimentary cycles produced by the rise and fall in the levels of Triassic lake systems. Many of these deposits contain rich vertebrate remains and there is therefore a potential to examine faunal change at the end of the Triassic to a remarkably fine resolution of time.

#### TERRESTRIAL VERTEBRATE EVOLUTION IN THE TRIASSIC

The Triassic period is perhaps the most important time in the evolution of terrestrial vertebrates. The end of the period saw the evolution of most modern terrestrial vertebrates, so that the first fossil mammals, crocodiles, turtles, sphenodontians, lissamphibians, and reportedly birds (Chatterjee, 1991, but see Ostrom, 1991) are known from Triassic deposits. Furthermore if sphenodontians are the closest sister group to lizards (Gardiner, 1982; Evans, 1984, 1988; Benton, 1985b), then by implication early lizards must also have been present by the end of the Triassic. In addition to these "modern" groups the Triassic also witnessed the appearance of the first dinosaurs and pterosaurs.

The marine fossil record shows that there were three putative mass extinctions in the Triassic. Firstly the beginning of the period is marked by the greatest of all recognised extinctions, the so-called end Permian event. It has even been suggested that as few as 4% of all species present in the Permian world survived into the Triassic (McGhee, 1989). Secondly the period closes with another major extinction episode marking the beginning of the Jurassic. The third Triassic extinction occurs at the end of the Carnian stage. Some authors regard this as a relatively minor event (Olsen and Sues, 1986), whereas others argue that this is the most pronounced Upper Triassic mass extinction with a drastic decrease in diversity of many groups (Benton, 1992), and that the episode that followed at the close of the period (i.e at the Norian-Hettangian boundary) was little more than the final disappearance of these depauperate taxa.

#### Causes of Triassic extinctions

At the close of the Permian period the continents came together to form the supercontinent Pangaea (Figure 1). This major palaeogeographical change may have been responsible for many of the extinctions, particularly the drastic reduction in species from coastal waters. However the exact causes and timing are unknown and it may well have been the result of a number of complex factors occurring over a period of thousands or millions of years. There is little evidence in favor of a sudden drastic decline in the biota taking place in a matter of months or years, but an extinction over a much shorter period of time cannot be ruled out.

Throughout Triassic times the continents remained united, but the rifting which preceded the separation of North America from Europe and Africa in the Jurassic

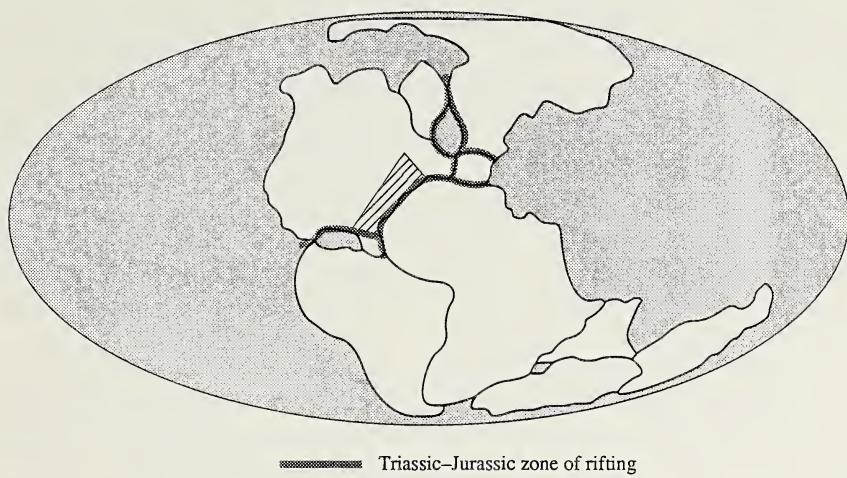


FIGURE 1. The relative position of the continental land masses towards the end of the Triassic period. The location of the Newark Supergroup is cross-hatched.

had begun (Figure 1). Evidence suggests that reptiles and amphibians migrated extensively, for there was a fairly homogeneous vertebrate fauna worldwide.

Major faunal changes occurred on land during Triassic times. As a result of the end Permian mass extinction the faunas were restricted at the beginning of the period, but the mammal-like reptiles re-radiated and the archosaurs ("thecodontians") and rhynchosaurids flourished. The end of the period saw the initial radiations of the dinosaurs and pterosaurs as well as the modern terrestrial vertebrate groups. However the transition from Middle to Late Triassic assemblages is poorly understood. There are two alternative theories accounting for the demise of the rhynchosaurids, the early archosaurs and many mammal-like reptile groups during the Triassic. Either they gradually died out through late Middle and early Late Triassic times through competitive replacement with the dinosaurs (Charig, 1984), or they disappeared suddenly at the end of the Carnian stage (early Late Triassic) allowing the dinosaurs to radiate opportunistically (Benton, 1983). It is difficult to reconcile the notion that families or orders of animals can compete with each other with the ecological concept of competition within or between species. In addition the role of competition in shaping ecological communities and its effects on evolutionary changes in species distribution or adaptation have been questioned by some authors (Connell, 1980; Simberloff, 1983; Price et al., 1984). Consequently I favor opportunistic replacement over the competitive replacement model. At the same time the evidence for a mass extinction of land vertebrates at the end of the Carnian stage is inconclusive and it has been suggested that it may in part merely represent a temporal discontinuity between the geographically disjunct Middle Triassic synapsid dominated assemblages characteristic of Gondwana (southern hemisphere), and the archosaur dominated assemblages typifying the Upper Triassic of Laurasia (northern hemisphere) (Sues and Olsen, 1991).

## THE TRIASSIC OF VIRGINIA

Late Triassic vertebrate localities in Virginia are particularly important and this survey follows the reviews by Olsen et al. (1978), Olsen (1988) and Sues and Olsen (1991). The early Mesozoic sediments of Virginia are part of what is known as the Newark Supergroup (Figure 2). The Newark Supergroup consists of a series of sediments deposited in rift basins running down the eastern part of North America. These rift basins formed during a 45 million year episode of crustal thinning and stretching which preceded the breakup of Pangaea during early Jurassic times. Within Virginia there are six main basins: Danville/ Dan River, Farmville, Scottsville, Richmond, Taylorsville, and the Culpeper basins (Figure 2). Recent research on these features has shown that their contained sediments sometimes contain abundant vertebrate remains.

A locality in the Richmond basin (Figure 2), which is of early to middle Carnian age, is yielding a diverse fauna of small tetrapods. To date it has produced abundant remains of a new traversodont eucynodont, *Boreogomphodon jeffersoni* (Sues and Olsen, 1991), which is very similar to *Luangwa* from the Anisian of Zambia and *Traversodon* from the Carnian of Brazil. Another eucynodont in the assemblage resembles *Microconodon* and *Pseudotricodonodon* from the Carnian of North Carolina and the Norian of western Europe respectively.

Archosaurian remains at the Richmond locality consist of a number of isolated phytosaur teeth, and armor and postcranial elements of an unusual new species which shows at least a superficial resemblance in its armor to *Doswellia* from the adjacent Taylorsville basin (Weems, 1980). The structure of recently described venom-conducting teeth is also most consistent with an archosaur (Sues, 1991).

The abundant eucynodont synapsids are consistent with Gondwanan faunas whilst the phytosaurs show affinity to Upper Triassic Laurasian assemblages. Triassic sediments in the Deep River Basin (Figure 2) of North Carolina are slightly younger (middle Carnian) than the Richmond deposits, and they have produced tetrapod assemblages containing mostly phytosaurs and suchian archosaurs. Synapsids, including *Microconodon*, are rare. The occurrence of a dominantly "Gondwanan" type fauna from an early to middle Carnian locality in the Northern hemisphere suggests that previous distinctions between tetrapod assemblages of Gondwana and Laurasia may actually reflect age differences rather than a basic geographic separation. Furthermore, Sues (1991) has suggested that the rare occurrence of synapsids in the phytosaur and suchian archosaur dominated Middle Carnian assemblages of the Deep River basin in North Carolina indicates a Carnian faunal turnover rather than a major extinction at the Carnian-Norian boundary.

A second vertebrate-bearing locality in the Virginian Triassic occurs in the Late Carnian Cow Branch Formation. It is situated in the Danville/ Dan River basin (Figure 2), and it contains an exceptional flora and fauna (Olsen et al., 1978; Olsen, 1979). The vertebrate fauna described to date includes articulated fish and abundant beautifully preserved skeletons of the tanystropheid, *Tanytrachelos*, with some preservation of soft tissues. However the invertebrate fauna (which includes a diverse number of insects) and the flora are still to be described fully.

Disarticulated remains of *Tanytrachelos* are also known from a number of other Triassic localities in the Newark Supergroup, in particular from Norian sediments (Olsen and Flynn, 1989). On the other hand lithologically similar sediments to those

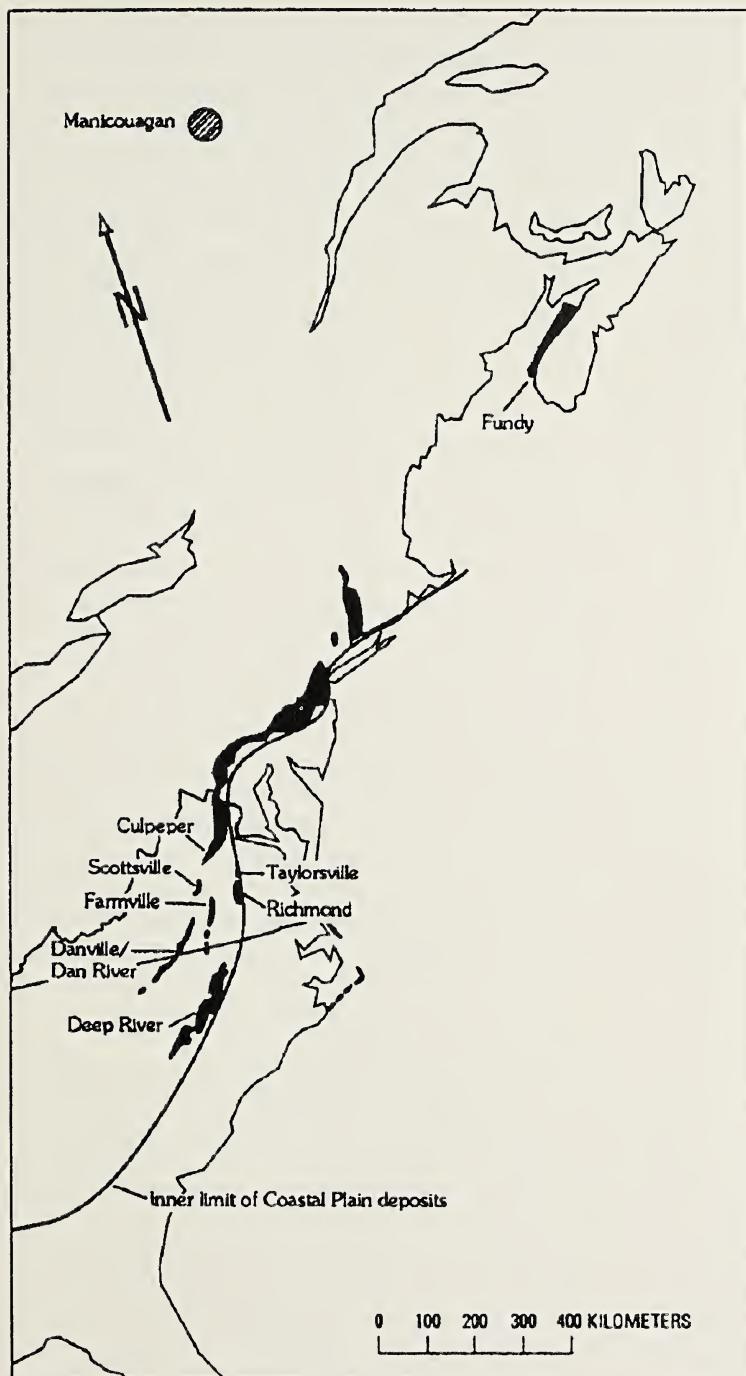


FIGURE 2. Occurrence of the Newark Supergroup sedimentary basins. After Olsen et al. (1987).

of the Cow Branch Formation in the Newark Supergroup which are Early Jurassic in age completely lack *Tanytrachelos*, despite the presence of articulated fish. Olsen (1992) has suggested that the lack of articulated *Tanytrachelos* specimens in the Norian of the Newark Supergroup is a function of the absence of units bearing articulated fish, but that the absence of any *Tanytrachelos* material in the Jurassic sections is a real phenomenon and reflects a Triassic-Jurassic extinction event.

The Danville/Dan River locality also serves to illustrate an extremely important facet of the research into many of the sedimentary basins of the Newark Supergroup. Olsen (1986) showed that the sediments consist of repetitive sequences representing fluctuations in the levels of very large lakes. Changes in precipitation resulted in large scale increases and decreases in lake depth. Thus at localities such as the Dan River site and also at the Culpeper Stone Company Quarry in the Culpeper basin (Figure 2), repetitive sequences of massive mudcracked mudstones (deposited during lowstands) grade into deep water microlaminated muds (deposited during highstands). There is a sharp contact between cycles, but only a gradational change in lithology within cycles. This cyclic pattern has been compared with Quaternary sections exhibiting major climate cycles apparently controlled by variations in the earth's orbit (Olsen, 1986). Studies of Quaternary sections indicate that there are 21,000 year climate cycles corresponding to the precession of the equinoxes, 41,000 year climate cycles resulting from the variation of the tilt of the earth's axis relative to an axis perpendicular to the orbital plane, and approximately 95,000, 123,000 and 413,000 year climate cycles resulting from eccentricity cycles. Van Houten recognised several orders of cycles in the Newark Supergroup sedimentary sequences, and Olsen (1986) argued that such Van Houten cycles corresponded to 25,000 (precession of the equinoxes), 45,000 (obliquity cycle), 100,000, 133,000 and 400,000 years (eccentricity cycles). Repetition of these cycles appear to have continued throughout the 45 million year period during which the Newark Supergroup sediments were deposited. Since such sequences are widespread throughout the Newark Supergroup it is possible to determine the relative ages of sediments at any extensive quarry outcrop to within a few thousand years. In addition, on the basis of these characteristic cycles it may now be possible in some cases to cross-correlate sections within the Newark basins.

#### Absolute Dating of the Triassic-Jurassic Boundary in the Newark Supergroup

In the northern part of the Newark Supergroup, vertebrate-bearing assemblages of Jurassic age are yielding further valuable information (Sues et al., 1987) which may eventually allow a detailed age correlation of the entire Newark Supergroup. In the Fundy basin the age of the faunas is constrained by two separate lines of evidence. Firstly pollen and spore data strongly indicate a maximum of a Hettangian age (i.e. immediately post-dating the Triassic-Jurassic boundary) (Olsen et al., 1987). Secondly the bone-bearing units are underlain by the extrusive North Mountain Basalt. The upper layers of this basalt unit are discontinuous in some areas, and interbed with the bone-bearing units. Conventional Potassium-Argon and Potassium-Argon isochron dates from the North Mountain Basalt, and therefore the vertebrate-bearing sediments, are consistent with an Early Jurassic age. The North Mountain Basalt in the Fundy basin correlates with the oldest of the extrusives known in the more southern Newark basins. The Triassic-Jurassic

boundary is palynologically fixed at about 30m below the oldest basalt (Orange Mountain in the Newark basin), which on the basis of climate cycles is about 100,000 years older than the oldest basalts. Typical lacustrine cycles occur interbedded with and underlying the basalt flows in the Newark basin. From these cycles, as well as other lines of evidence, the duration of the Newark extrusive episode has been estimated to be as short as 600,000 years (Olsen et al., 1987). Furthermore the vertebrate-bearing sediments immediately overlying the North Mountain Basalt in the Fundy basin are no more than 300,000 years younger than the boundary.

The Newark Supergroup therefore offers the opportunity to assess terrestrial vertebrate faunal turnover over a period of 45 million years (including the Triassic-Jurassic boundary), but at a much finer time resolution than is normally possible in Mesozoic sequences. Within the Newark Supergroup the data support an extinction event at the Triassic-Jurassic boundary with the sudden loss of taxa such as *Tanytrachelos*, various procolophonids and phytosaurs, which are abundant and ubiquitous to that point. In addition the evidence suggests a zero origination rate throughout the Hettangian (Olsen et al., 1987). Supposed originations in the Hettangian are equivocal. For instance the Gephyrosauridae have been recorded as an example of a Hettangian origination (Olsen and Sues, 1986), yet the relationships of basal sphenodontids remains unresolved (Fraser and Benton, 1989), and Fraser (1988) suggested that *Gephyrosaurus* together with the Triassic genera *Planocephalosaurus* and *Diphydontosaurus* may form a monophyletic taxon. Similarly, certain ichnotaxa, such as *Anomoepus*, might be cited as examples of Hettangian origination. Unfortunately the criteria for describing prints and trackways are not sufficiently well established to allow for age determinations based solely on ichnotaxa; but I have observed *Anomoepus*-like trackways in Triassic sediments in Virginia. Thus within the Newark Supergroup Early Jurassic faunas are characterised by the absence of certain Triassic taxa and, at present, no substantive evidence for the origination of new taxa. This is consistent with the proposal of a dramatic extinction event, at least locally. On the other hand the Newark Supergroup sequences do not suggest any major extinction event at the Carnian-Norian boundary.

#### GLOBAL TERRESTRIAL VERTEBRATE TURNOVER ACROSS THE TRIASSIC-JURASSIC BOUNDARY

The majority of Triassic and Jurassic vertebrate-bearing sequences in the rest of the world do not permit such a high resolution dating of the sediments. Therefore a global picture of faunal change across the Triassic-Jurassic boundary has been difficult to assess with any degree of confidence resulting in conflicting hypotheses regarding faunal turnover at the Triassic-Jurassic boundary (Olsen and Sues, 1986; Benton, 1992). Many of the classic vertebrate-bearing localities of the world are notoriously difficult to date. For instance the diverse range of British Mesozoic fissure deposits contain abundant and exceptionally preserved assemblages of reptiles and early mammals (Fraser, 1985), yet because of their isolation from normally bedded sequences it is generally only possible to assign a very approximate age to each assemblage. Even where vertebrates occur in well-bedded sediments such as the Lufeng Series of Yunnan, China, or the Stormberg Series of South

Africa, there are few unequivocal data to constrain the ages of the deposits (Colbert 1986).

Colbert (1958) exemplifies an early view that there was a catastrophic extinction marking the close of the Triassic period. However Olsen and Galton (1977) showed that many of the deposits which had previously been regarded as uppermost Triassic were in fact Early Jurassic in age. As a result many taxa thought to have disappeared at the end of the Triassic did in fact persist into the Jurassic, which in turn led Olsen and Galton to suggest that faunal turnover across the Triassic-Jurassic boundary followed a much more gradual pattern. However in recent years many more Early Mesozoic fossil discoveries have been made, and the opinion has once more shifted towards a catastrophic extinction event among terrestrial tetrapods in the Late Triassic, although, as mentioned earlier, there is some dispute with regard to the precise timing.

Although the Newark basins only give a picture of faunal turnover in the eastern part of the North American continent, Early Mesozoic faunas worldwide show a remarkable homogeneity, and many of the taxa in the Newark basins are now known from other Late Triassic and early Jurassic localities worldwide. Although some of these taxa appear to be relatively long ranging in time, research on the British fissure deposits indicates that some widespread forms may be very restricted (Fraser, 1992). Where such taxa occur in the Newark Supergroup it would be possible to use them as biostratigraphic indicators to date more accurately the sediments where they occur elsewhere.

Currently, research on the sphenodontids in the British fissure deposits indicates that the genus *Clevosaurus* (Figure 3) may be useful biostratigraphically (Fraser, 1992). At least three species are known in the fissure deposits, and apparently none of them have overlapping ranges (Fraser, 1988). The same (or at least a closely related) genus occurs in restricted sections of the Newark Supergroup (Sues, pers. comm.) and the Lufeng series of Yunnan, China (Wu, 1991). In some cases there even seems to be a very close resemblance at the species level in what are today disjunct occurrences of fossil sphenodontids.

The procolophonids, although widespread and abundant in Triassic rocks worldwide, are poorly known. However there has been renewed interest in the group recently. I have observed that some of the forms which occur in the Newark Supergroup and in British Triassic sediments appear to be very closely related indeed, and may prove to be congeneric. As mentioned above, within the Newark basins procolophonids occur right up to the Triassic-Jurassic boundary, but are completely absent above it. Elsewhere, although the position of the boundary may not be as well documented, procolophonids do not appear to extend beyond the end of the Triassic. Additional taxa which apparently do not survive beyond the Triassic include the phytosaurs and aetosaurs. Together with groups such as the sphenosuchid crocodiles, which do extend beyond the Triassic and also occur in the Newark Supergroup, it may be possible to develop a high resolution biostratigraphy for Early Mesozoic terrestrial vertebrates.

This work on the biostratigraphy is only in the preliminary stages, and to date the results are insufficient to indicate whether there was a catastrophic extinction episode at the Carnian-Norian or the Norian-Hettangian boundaries. However it is interesting to note that the Manicouagan impact structure in Quebec, Canada is

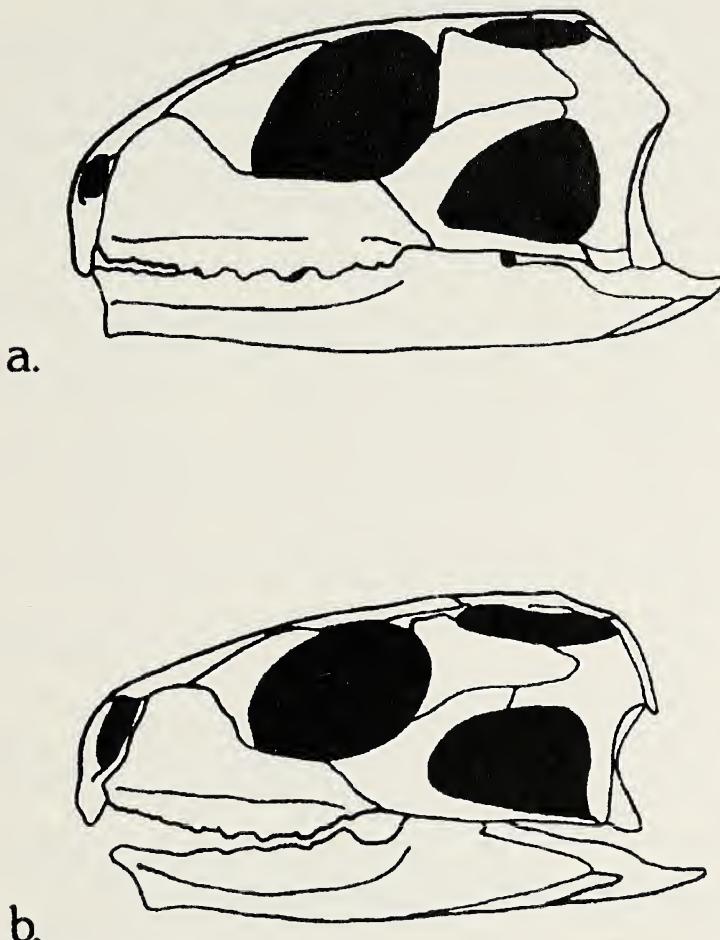


FIGURE 3. Skulls of clevosaurs (Sphenodontida) in lateral view. a) *Clevosaurus wangi* and b) *Clevosaurus hudsoni*. ((a) after Carroll and Wild, 1992 and (b) after Fraser, 1988.)

a potential candidate for the cause of extinctions at the end of the Triassic. It has not proved possible to obtain a precise age for this structure, and dates range from 220 to 200 million years old. Accordingly either an end Carnian or an end Norian extinction episode could conceivably be attributed to the Manicouagan impact. Olsen et al. (1987) made the observation that the Triassic-Jurassic extinctions seem to parallel those at the Cretaceous-Tertiary boundary, and that, with the exception of dinosaurs (excluding birds), pterosaurs and a few mammal-like reptiles, the terrestrial vertebrate groups that survived the Triassic also survived the Cretaceous.

The recent research on the Triassic vertebrates of Virginia and eastern North America has added to our knowledge of the nature of Late Triassic terrestrial tetrapods. Further comparison of the Newark Supergroup fossil assemblages with contemporaneous faunas from elsewhere in the world may ultimately provide the answers to the nature of Early Mesozoic extinctions.

## ACKNOWLEDGEMENTS

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## LITERATURE CITED

- Alvarez, L.W., W. Alvarez, F. Asaro, and H.V. Michel. 1980. Extraterrestrial cause for the Cretaceous-Tertiary extinction. *Science* 208: 1095-1108.
- Benton, M.J. 1983. Dinosaur success in the Triassic: a noncompetitive ecological model. *Quarterly Review of Biology* 58: 29-55.
- \_\_\_\_\_. 1985a. Mass extinction among non-marine tetrapods. *Nature* 316: 811-814.
- \_\_\_\_\_. 1985b. Classification and phylogeny of the diapsid reptiles. *Zoological Journal of the Linnean Society* 84: 97-164.
- \_\_\_\_\_. 1992. What really happened in the Late Triassic? *Historical Biology*. In press.
- Carroll, R.L. and R. Wild. 1992. Marine members of the diapsid order Sphenodontida. In Fraser, N.C. and H.-D. Sues eds. *Early Mesozoic Small Tetrapods*. Columbia University Press, New York. In press.
- Charig, A.J. 1984. *A new look at the dinosaurs*. Heinemann, London.
- Chatterjee, S. 1991. Cranial anatomy and relationships of a new Triassic bird from Texas. *Philosophical Transactions of the Royal Society of London, B* 332: 277-346.
- Colbert, E.H. 1958. Tetrapod extinctions at the end of the Triassic period. *Proceedings of the National Academy of Sciences U.S.A.* 44: 973-977.
- Colbert, E.H. 1986. Historical aspects of the Triassic - Jurassic boundary problem. 1986. Pages 9-19 in Padian, K. ed. *The beginning of the age of dinosaurs*. Cambridge University Press, Cambridge.
- Connell, J.H. 1980. Diversity and the coevolution of competitors, or the ghost of competition past. *Oikos* 35: 131-138.
- Evans, S.E. 1984. The classification of the Lepidosauria. *Zoological Journal of the Linnean Society* 82: 87-100.
- \_\_\_\_\_. 1988. The early history and relationships of the Diapsida. Pages 221-260 in Benton, M.J. ed. *The Phylogeny and Classification of the Tetrapods*, Volume 1: Amphibians, Reptiles, Birds. Clarendon Press, Oxford.
- Fraser, N.C. 1985. Vertebrate faunas from Mesozoic fissure deposits of South-west Britain. *Modern Geology* 9: 273-300.
- \_\_\_\_\_. 1988. The osteology and relationships of *Clevosaurus* (Reptilia: Sphenodontida). *Philosophical Transactions of the Royal Society of London, B* 321: 125-178.
- \_\_\_\_\_. 1992. Small tetrapods from Late Triassic fissure deposits in Britain. In Fraser, N.C. and H.-D. Sues eds. *Early Mesozoic Small Tetrapods*. Columbia University Press, New York. In press.

- \_\_\_\_\_. and M.J. Benton. 1989. The Triassic reptiles *Brachyrhinodon* and *Polysphenodon* and the relationships of the sphenodontids. *Zoological Journal of the Linnean Society*, 96: 413-445.
- Gardiner, B.G. 1982. Tetrapod classification. *Zoological Journal of the Linnean Society* 74: 207-232.
- Hallam, A. 1981. The end-Triassic bivalve extinction. *Palaeogeography, Palaeoclimatology, Palaeoecology* 35: 1-44.
- McGhee, G.R. 1989. Catastrophes in the history of life. Pages 26-50 in Allen, K.C. and D.E.G. Briggs eds. *Evolution and the fossil record*. Belhaven Press, London.
- Newell, N.D. 1967. Revolutions in the history of life. Pages 62-92 in Albritton, C.C. ed. *Uniformity and Simplicity* Geological Society of America Special Papers 89: 62-92.
- Olsen, P.E. 1979. A new aquatic eosuchian from the Newark Supergroup (Late Triassic-Early Jurassic) of North Carolina and Virginia. *Postilla* 1176: 1-14.
- \_\_\_\_\_. 1986. A 40-million-year lake record of early Mesozoic orbital climatic forcing. *Science* 234: 842-848.
- \_\_\_\_\_. 1988. Paleontology and paleoecology of the Newark Supergroup (early Mesozoic, eastern North America) Pages 185-230 in Manspeizer, W. ed. *Triassic-Jurassic rifting and the opening of the Atlantic Ocean*. Elsevier, Amsterdam.
- \_\_\_\_\_. 1992. Field guide to three late Triassic tetrapod sites in Virginia and North Carolina (Culpeper, Richmond, and Dan River basins, Newark Supergroup). In Fraser, N.C. and H.-D. Sues eds. *Early Mesozoic Small Tetrapods*. Columbia University Press, New York. In press.
- \_\_\_\_\_. and J.J. Flynn. 1989. Field guide to the vertebrate paleontology of Late Triassic rocks in the southwestern Newark basin (Newark Supergroup, New Jersey and Pennsylvania). *The Mosasaur* 4: 1-43.
- \_\_\_\_\_. and P.M. Galton. 1977. Triassic-Jurassic tetrapod extinctions: are they real? *Science* 197: 983-986.
- \_\_\_\_\_. , C.L. Remington, B. Cornet, and K.S. Thomson. 1978. Cyclic change in Late Triassic lacustrine communities. *Science* 201: 729-733.
- \_\_\_\_\_. , N.H. Shubin, and M.H. Anders. 1987. New Early Jurassic tetrapod assemblages constrain Triassic-Jurassic extinction event. *Science* 237: 1025-1029.
- \_\_\_\_\_. and H.-D. Sues. 1986. Correlation of continental Late Triassic and Early Jurassic sediments, and patterns of the Triassic-Jurassic tetrapod transition. Pages 321-351 in Padian, K. ed. *The Beginning of the Age of Dinosaurs*. Cambridge University Press, Cambridge.
- Ostrom, J.H. 1991. The bird in the bush. *Nature* 353: 212.
- Price, P.W., C.N. Slobodchikoff, and W.S. Gaud. 1984. *A New Ecology*. Wiley Interscience, New York.
- Raup, D.M. and J.J. Sepkoski. 1982. Mass extinctions in the marine fossil record. *Science* 215: 1501-1503.
- Raup, D.M. and J.J. Sepkoski. 1984. Periodicities of extinctions in the geologic past. *Proceedings of the National Academy of Sciences U.S.A.* 81: 801-805.

- Sepkoski, J.J. 1982. Mass extinctions in the Phanerozoic oceans: a review. Geological Society of America Special Paper 190: 283-289.
- Simberloff, D. 1983. Competition theory, hypothesis testing, and other community ecological buzzwords. *American Naturalist* 122: 626-635.
- Sues, H.-D., 1991. Venom-conducting teeth in a Triassic reptile. *Nature*. In press.
- \_\_\_\_\_, and P.E. Olsen. 1991. Triassic vertebrates of Gondwanan aspect from the Richmond basin of Virginia. *Science* 249: 1020-1023.
- \_\_\_\_\_, P.E. Olsen, and N.H. Shubin. 1987. A diapsid faunule from the Lower Jurassic of Nova Scotia, Canada. Pages 205-207 in Currie, P.J. and E.H. Koster ed. Mesozoic Terrestrial Ecosystems. Occasional paper of the Tyrrell Museum of Palaeontology 3: 205-207.
- Weems, R.E. 1980 An unusual newly discovered archosaur from the Upper Triassic of Virginia, U.S.A. *Transactions of the American Philosophical Society* 70: 1-53.
- Wu, X.-C. 1991. The comparative anatomy and systematics of Mesozoic sphenodontians. Unpublished PhD. dissertation, McGill University, Montreal.

## Tertiary Molluscan Assemblages from the Salisbury Embayment of Virginia

Lauck W. Ward, Virginia Museum of Natural History  
Martinsville, VA 24112

### ABSTRACT

The Tertiary strata of the Salisbury embayment of Maryland and Virginia contain an excellent record of molluscan assemblages for the last 65 million years. Various basin configurations, sea-level fluctuations, and climatic trends combined to produce a habitat increasingly provincial in nature, in which a predominately temperate assemblage evolved. Paleocene and Eocene molluscan assemblages closely resemble those in the Gulf states such as Alabama and Mississippi. Lower Oligocene beds in the Salisbury embayment are known to occur only in several deep boreholes, but upper Oligocene beds crop out. These beds contain mollusks that became the dominant taxa during the Miocene and most of the Pliocene. Some of the taxa, such as *Glossus*, *Ecphora*, *Chesapecten*, and *Marvacrassatella*, were extremely successful in the temperate Miocene–Pliocene embayment but became extinct during the post-Yorktown (late Pliocene) sea-level fall. That event, during which both sea level and temperatures dropped, resulted in the apparent extinction of approximately 55% of the Yorktown species. The Chowan River embayment, which followed in the late Pliocene, lacked many of the previously abundant taxa and was inhabited principally by subtropical species, which migrated northward as temperatures rose.

Key Words: Chesapeake Bay, paleogeography, mollusks, extinctions, climate

### INTRODUCTION

Tertiary beds exposed along the shores of the Chesapeake Bay and its tributaries contain an excellently preserved record of marine transgressions. This record consists of a number of unique, mappable beds, each with its own assemblage of marine fossils, that may be traced and correlated over the Maryland and Virginia Coastal Plains.

In order to reconstruct the geologic history of the Chesapeake Bay area, a thorough knowledge of the lithologic nature of the various beds is necessary. With these data assimilated, a series of models approximating the changing basinal areas can be constructed.

The fossil assemblages, consisting principally of mollusks, help to correlate the lithic units and give valuable information on the paleoenvironment and paleoecology. Assemblages can be correlated confidently to time-equivalent geologic units to the south and help to develop a regional paleogeographical model.

### GEOLOGIC SETTING

Stratigraphic units exposed in the Chesapeake Bay area consist of Mesozoic and Cenozoic Coastal Plain beds deposited in a tectonic downwarp known as the Salisbury embayment (Figure 1) (Ward, 1984). The Salisbury embayment includes

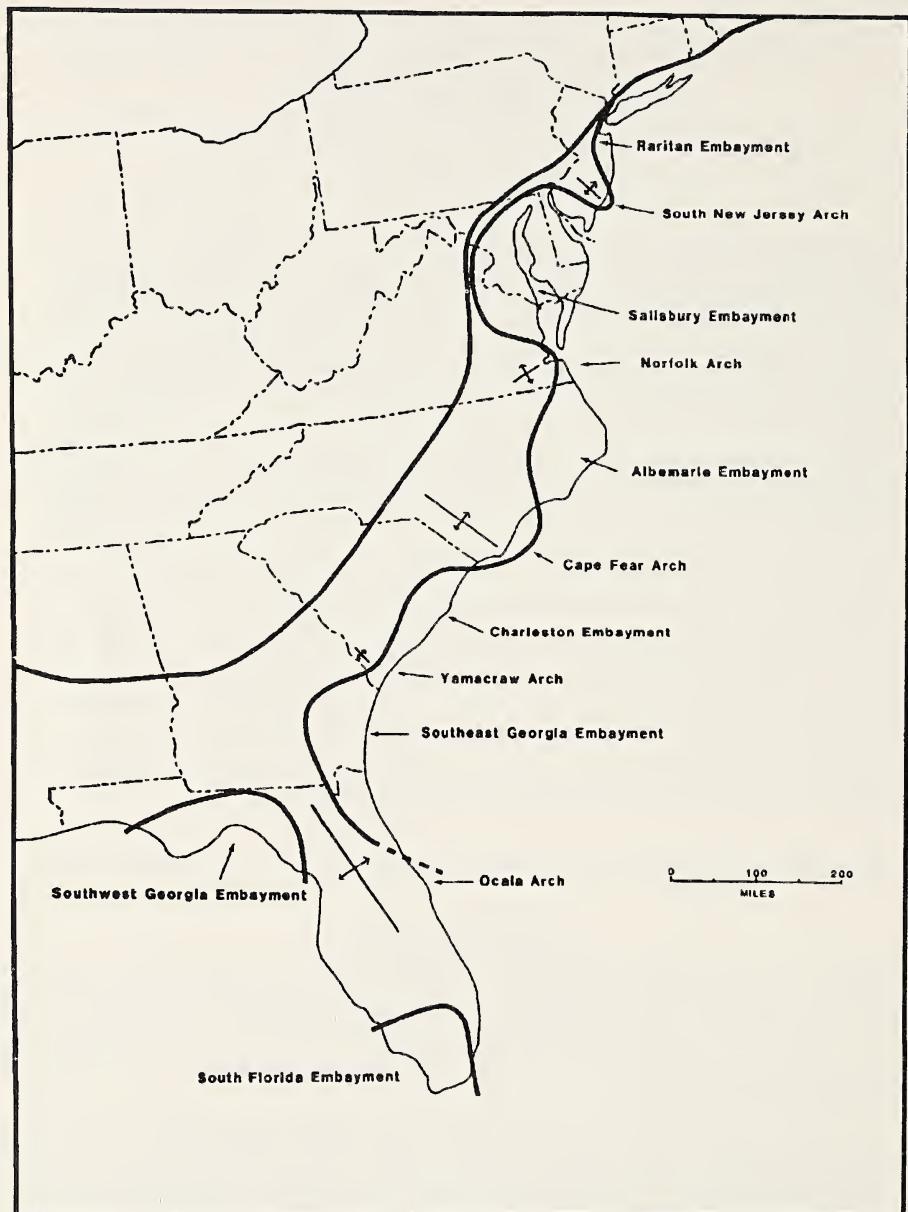


FIGURE 1. Map showing principal basins and arches of the Atlantic Coastal Plain.

parts of Virginia, Maryland, Delaware, and southern New Jersey and is bordered on the north and south by the South New Jersey arch and the Norfolk arch, respectively. Subsurface data indicate that these arches are characterized by stratigraphic thinning or truncation of Cretaceous and Tertiary age formations. The basement complex underlying the embayment includes Precambrian and Paleozoic age crystalline rocks and Mesozoic age rift-basin fill. The Salisbury embayment was the site of intermittent marine overlap and deposition during the Early and Late Cretaceous and most of the Tertiary. Beds are of fluvial, deltaic, and open-shelf origin and were deposited in a wedge-like configuration with their thin, westward edge overlapping the Piedmont. To the east, the Coastal Plain deposits thicken to several thousand feet near the present coastline.

The lithology, thickness, and dip of the various formations deposited in the Salisbury embayment are, to a great extent, structurally controlled. This tectonism occurred at several local and regional scales. Tectonism on a regional scale involved tilting of the entire Atlantic continental margin. Of lesser importance was the independent structural movement of the various basins, or depocenters, and the intervening arches, or high areas. These high and low areas moved independently of each other, creating a stratigraphic mosaic that is unique from basin to arch. Various tectonic models included block-faulting and possible movement of the landward extensions of oceanic transform faults. Variations in the distribution and thickness of Cretaceous and Tertiary deposits also suggest the gradual migration of basins through time. Other structural deformation in the Salisbury embayment consists of localized, down-dropped grabens that occur along northeast-southwest trending lineaments. These grabens are related to early Mesozoic rifting and caused certain areas to be unstable. These areas were reactivated during the Cretaceous and Tertiary, possibly due to sediment loading. This resulted in structural highs, behind which finer sediments accumulated. Thus, each of these various structural elements contributed to the overall depositional patterns on the Coastal Plain and in the Salisbury embayment.

Lower Tertiary deposits consist of glauconitic silty, sands containing varying amounts of marine shells. The Tertiary beds are principally marine-shelf deposits. Fluvial, deltaic, and nearshore-shelf facies are generally lacking. The same is true for the upper Tertiary marine beds, which consist of diatomaceous silts and silty and shelly sands. However, sands and gravels of fluvial and deltaic origin cap most of the higher interfluvies in the Salisbury embayment area and are thought to be Miocene, Pliocene, and/or Pleistocene ages.

The Salisbury embayment had a warm-temperate to subtropical marine setting through much of its history. During the late Tertiary, a portion of the temperate molluscan fauna became endemic so that abrupt cooling in the late Pliocene caused a major local extinction involving taxa that had been successful since the Oligocene.

#### TERTIARY HISTORY OF THE SALISBURY EMBAYMENT

The Salisbury embayment and the entire Atlantic Coastal Plain have had a complex history. In contrast to "passive margin" descriptions, this was a structurally dynamic area whose sedimentary history clearly shows the effects of structural movement as well as of global sea-level events. To identify and eliminate local tectonic "noise" and detect actual global sea-level changes, one must compare the

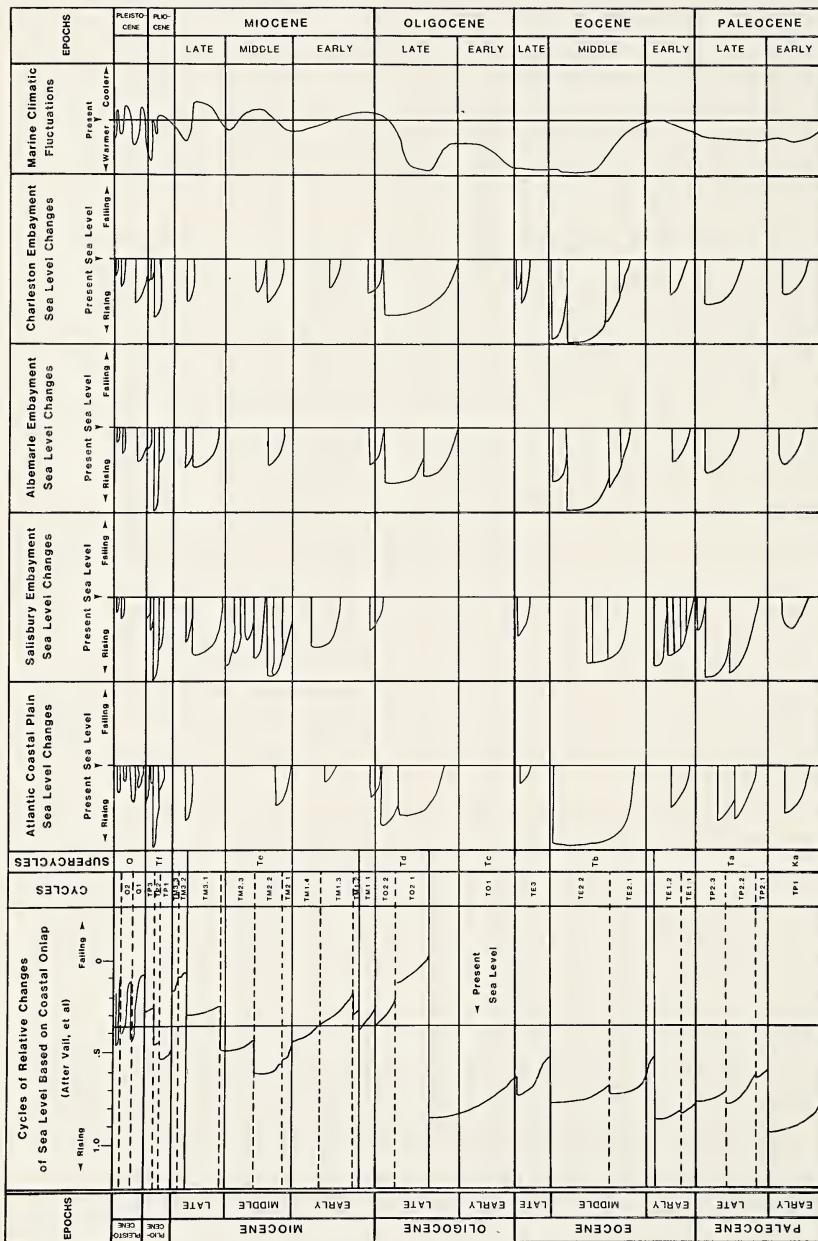


FIGURE 2. Onlap-offlap history of the Atlantic Coastal Plain, based on onshore outcrop and subsurface data. Sea-level fluctuations in the Salisbury, Albemarle, and Charleston embayments are plotted against a chart of cycles and supercycles by Vail and Mitchum (1979). Data from the basins are combined to approximate global sea-level events as seen along the Atlantic Coastal margin. The marine climate curve represents conditions in the Salisbury embayment and is based on data from fossil molluscan assemblages.

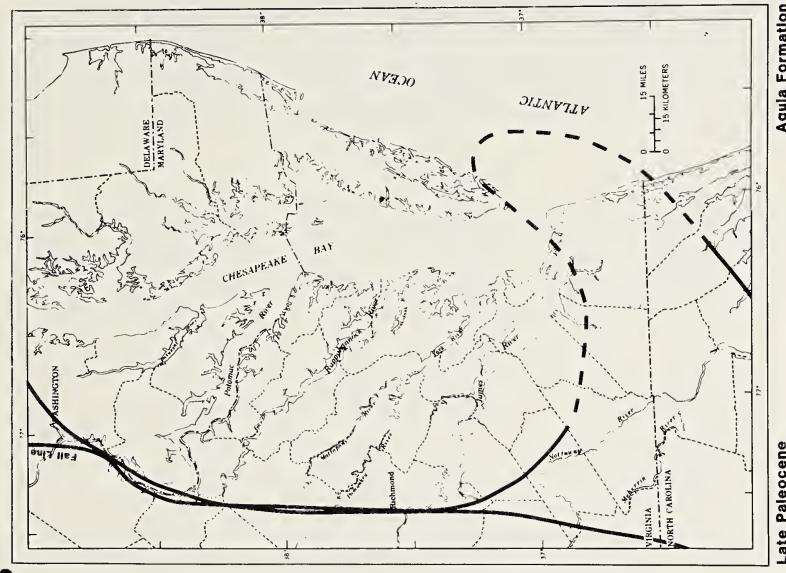
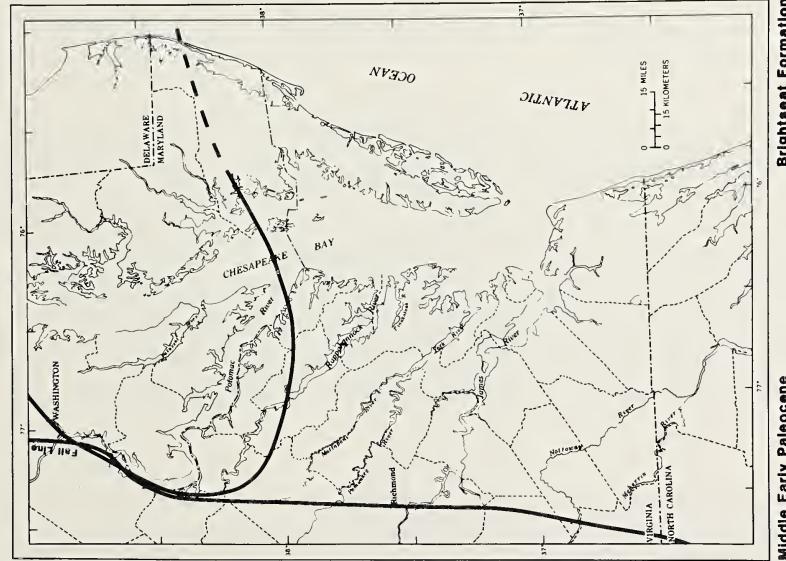
**B****A**

FIGURE 3A & 3B. Maps showing depositional basins during the Paleocene. Dashed lines indicate areas where boundary data are lacking.

C

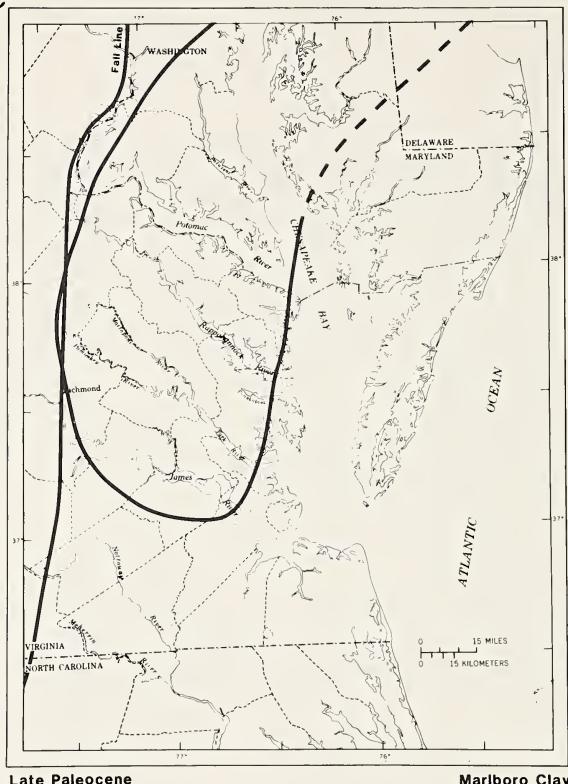


FIGURE 3C. Maps showing depositional basins during the Paleocene. Dashed lines indicate areas where boundary data are lacking.

detailed stratigraphic records of several embayments. In Figure 2, the sea-level curves of three principal Atlantic Coastal Plain basins (Salisbury embayment, Albemarle embayment, and Charleston embayment) are summarized. A fourth curve for the Atlantic Coastal Plain combines the data obtained in the three basins and attempts to show the actual record of sea-level fluctuations. These curves are plotted against the cycles and super-cycles of Vail and Mitchum (1979). The curves are based on my interpretation of onshore outcrop and subsurface data. No attempt has been made to plot sea-level changes beyond the present coastline. The trends discussed below are based on the onlap relationships of formations in the three basins.

#### PALEOCENE

In the middle early Paleocene, there is evidence of a moderately strong marine pulse. Sediments of the Brightseat Formation in the Salisbury embayment (Figure 3A), the Jericho Run Member of the Beaufort Formation in the Albemarle embayment, and the Black Mingo Formation in the Charleston embayment were deposited during this transgression. Another extensive onlap sequence occurred during the late Paleocene and lasted almost that entire period. In the Salisbury embayment, beds associated with the latter event are included in the Aquia

Formation (Figure 3B). There are at least two recognizable sea-level pulses, represented by the Piscataway and Paspatansa Members, involved in that sequence. A final small transgression, probably only in the Salisbury embayment, resulted in the deposition of the Marlboro Clay (Figure 3C).

Paleocene mollusks were relatively diverse and essentially the same assemblage occurred from Maryland to Texas. The assemblage was dominated by large *Turritella*, but also common were very large *Ostrea*, culminating in *Ostrea sinuosa*, which can be 28 cm in diameter. The fauna seems to indicate warm, temperate marine conditions.

### EOCENE

During the early Eocene a moderately extensive transgression occurred in the Salisbury embayment (Potapaco Member of the Nanjemoy Formation, Figure 4A). In the late early Eocene a second transgression occurred, which is reflected in the Salisbury embayment by the Woodstock Member of the Nanjemoy Formation (Figure 4B).

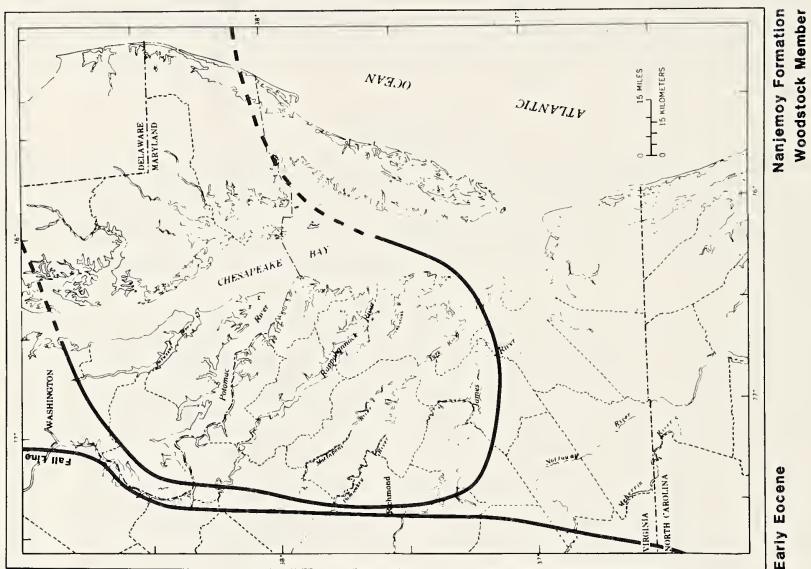
The most extensive transgression during the Tertiary occurred in the middle Eocene. In Virginia and Maryland it took place during the middle middle Eocene and resulted in the deposition of the Piney Point Formation (Figure 4C). To the south, equivalent strata consist of carbonate beds: Castle Hayne Formation in North Carolina, Moultrie Member of the Santee Limestone and McBean Formation in South Carolina and Georgia, and Lisbon Formation in Georgia and Alabama. Beds associated with this event are present in all areas of the Gulf Coastal Plain. It is clear that these deposits record a global sea-level rise. At least five small transgressions are reflected in the middle Eocene sequence, but they are plotted as a single event in Figure 2 because of the lack of correlative data. During the late Eocene, a small-scale transgression took place in Virginia (the Chickahominy Formation of Cushman and Cederstrom, 1945; Figure 4D). This thin unit contrasts with the thick stratigraphic sequence deposited in the Gulf area at that time. The Gulf deposits suggest a high sea-level stand, but the meager upper Eocene record in the Atlantic basins indicates a general sea-level lowering, unless most of that area was tectonically emergent.

The molluscan assemblages in the lower Eocene were meager by comparison with those in the Paleocene but by the middle Eocene they were extremely diverse. The mollusks in the late Eocene of Virginia are unknown, since the beds are only in the subsurface. Evidence in Alabama suggests a large extinction at the end of the middle Eocene, a repopulation during the late Eocene, and another large extinction event at the end of the Eocene. The Salisbury embayment was at least subtropical during the Eocene with a tropical setting just to the south of the Norfolk Arch, in the Carolinas.

### OLIGOCENE

During the early Oligocene, a thick sequence of beds was deposited in the Gulf, while in the Atlantic region there are only thin subsurface units of that age. In the late Oligocene, data indicate a relatively high stand, which resulted in the deposition of beds in the Charleston embayment, Albemarle embayment, and the Gulf. During the very late Oligocene or very early Miocene a brief, small-scale, high stand left a sedimentary record in the Salisbury embayment (Old Church Formation,

B



A

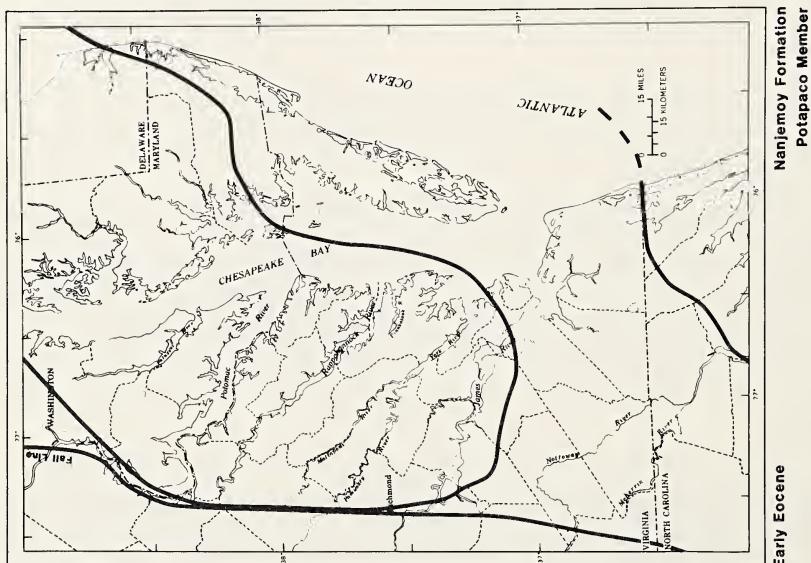
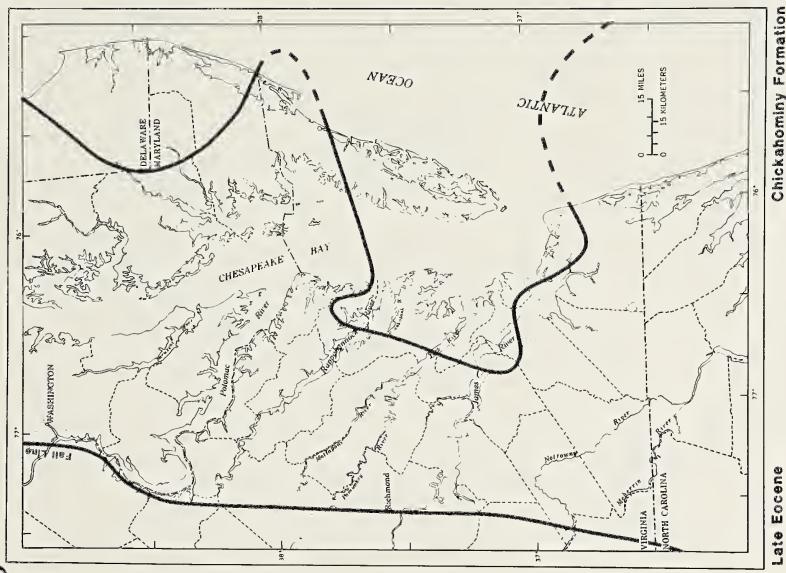


FIGURE 4A & B. Maps showing depositional basins during the Eocene. Dashed lines indicate areas where boundary data are lacking.

D



C

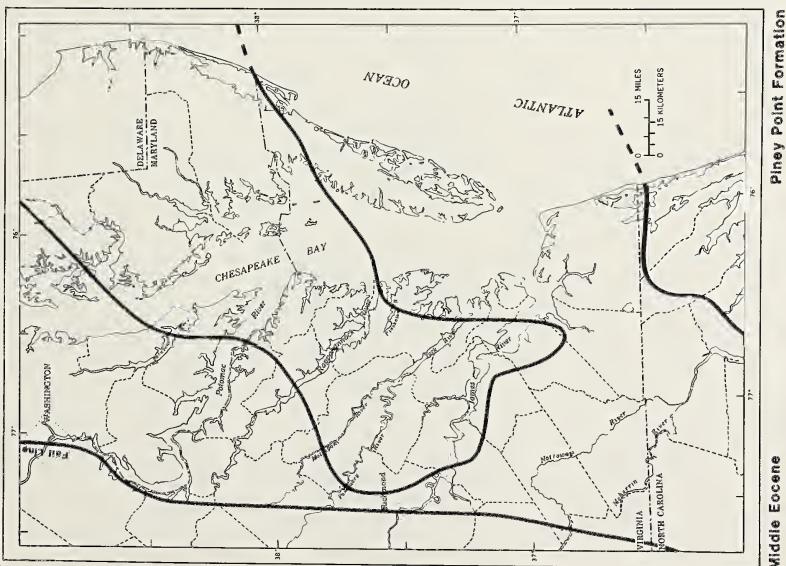
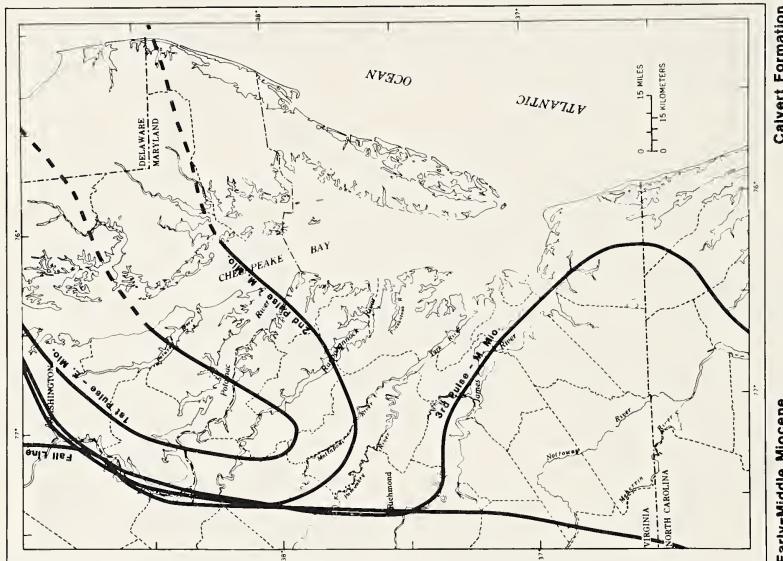
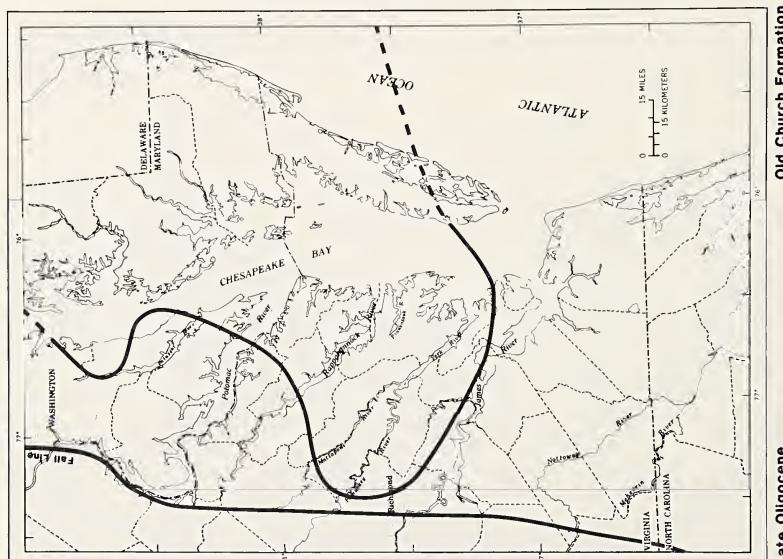


FIGURE 4C & D. Maps showing depositional basins during the Eocene. Dashed lines indicate areas where boundary data are lacking.

B



A

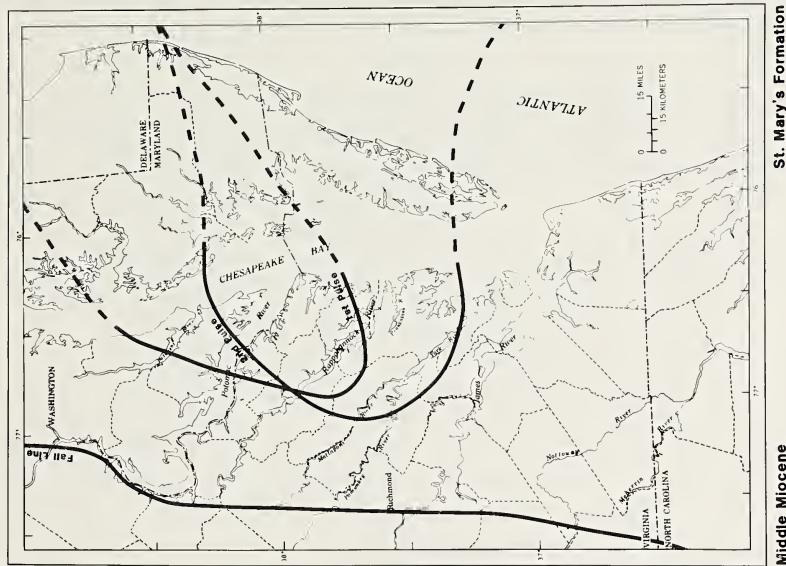


Late Oligocene  
Old Church Formation

Early-Middle Miocene  
Calvert Formation

FIGURE 5A & B. Maps showing depositional basins from the late Oligocene thru the middle Miocene. Dashed lines indicate areas where boundary data are lacking.

D



C

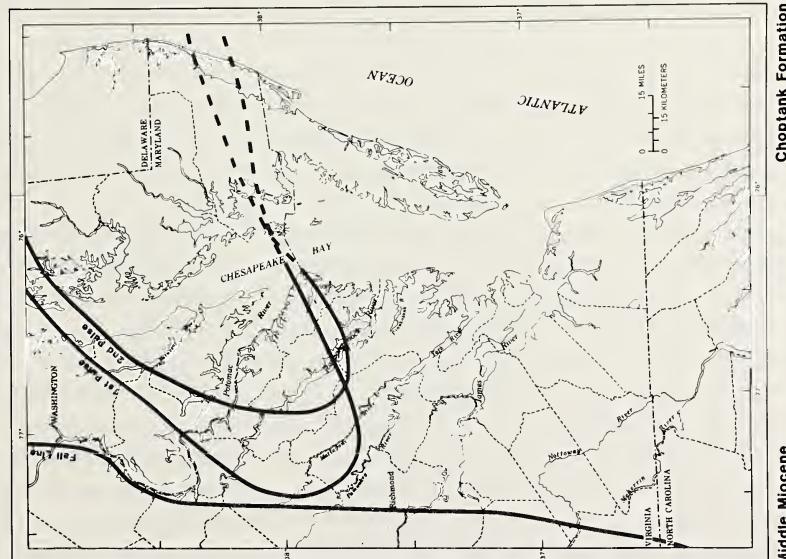


FIGURE 5C & D. Maps showing depositional basins from the late Oligocene thru the middle Miocene. Dashed lines indicate areas where boundary data are lacking.

Figure 5A). In spite of the thinness of these deposits, their wide occurrence is good evidence for a global sea-level rise and the submergence of much of the Atlantic Coastal Plain (Ward, 1985).

Molluscan assemblages in the Old Church Formation are mixed, with both tropical and cool water forms present. This condition may have been produced by upwelling along the coast.

### MIOCENE

Following the Old Church transgression and a brief regression, onlap in the Salisbury embayment during the Miocene is characterized by nearly continuous sedimentation punctuated by short breaks, resulting in a series of thin, unconformity-bounded beds. Three of these transgressions produced the silty sands and diatomaceous clays of the Calvert Formation (Shattuck, 1902; 1904; Figure 5B). The diatom assemblages indicate the first and second transgressions occurred in the late early Miocene, and the third in the early middle Miocene (Abbott, 1978; Andrews, 1978). The axis of the depocenter was still to the northeast and it was apparently a restricted basin. Diatomaceous clays accumulated deep in the embayment while coarser-grained, sandy deposits predominate in a seaward direction. Small-scale marine pulses brought coarser sediments deep into the embayment and still-stands resulted in clay accumulations. This formed cyclic deposits of alternating thick beds of clay and sand. Each of the Calvert pulses was successively more extensive; the third pulse partially overlapped the Norfolk arch and extended into the Pungo River sea in the Albemarle embayment.

In the middle and late middle Miocene, the Salisbury embayment was again the site of two brief transgressions. Both were less extensive than the earlier Calvert seas and brought coarser sediments deeper into the embayment (Figure 5C). Beds of the first transgression, including the Drumcliff and St. Leonard Members (of Gernant, 1970) of the Choptank Formation, unconformably overlie the Calvert Formation. The second pulse of the Choptank, which corresponds to the Boston Cliffs Member of Gernant (1970), unconformably overlies beds of the first pulse. Molluscan assemblages indicate cool-temperate to warm-temperate, shallow-shelf, open-marine conditions.

In the early late Miocene another pair of marine transgressions occurred in the Virginia-Maryland area (Figure 5D). Predominantly clayey sands were deposited, with some beds containing a prolific and diverse molluscan assemblage. These beds, which have been assigned to the St. Marys Formation, conformably overlie the Choptank Formation and, in turn, are unconformably overlain by beds of the second pulse, which corresponds to Shattuck's (1904) zone 24. Both units contain abundant and diverse molluscan assemblages that indicate shallow-shelf, open-marine, warm-temperature to subtropical conditions. During the second pulse, the locus of marine deposition shifted substantially to the south. This shift indicates an end of the northeast-southwest depositional alignment that appeared to have dominated in the Salisbury embayment from the Paleocene to the middle Miocene. After the shift, the principal basinal area was centered in Virginia, while Maryland was largely emergent.

After a break of approximately 1.5–2.0 Ma, marine sedimentation resumed with a large-scale transgression in the late late Miocene (Figure 6A). It began with

localized subsidence in central Virginia that caused the deposition of a thick sequence of inner-bay to shallow-shelf sediments, termed the Claremont Manor Member of the Eastover Formation (Ward and Blackwelder, 1980). The Claremont Manor Member is a poorly sorted mixture of clay and sand with the finer material concentrated in the westward portion of the basin. Toward the center, fine sands dominate and contain large concentrations of mollusks in the beds. Some of the nearshore clays deposited at that time contain appreciable concentrations of diatoms. Molluscan assemblages found in the Claremont Manor Member are less diverse than in either of the previous pulses in the St. Marys Formation and are less diverse than the subsequent Cobham Bay Member of the Eastover Formation. The composition of the fauna suggests cool to mild temperature conditions in a somewhat protected and restricted embayment.

After a brief low stand, a renewed transgression in the late Miocene resulted in a very thin, but widespread, marine deposit termed the Cobham Bay Member of the Eastover Formation (Ward and Blackwelder, 1980; Figure 6B).

The marine conditions fluctuated constantly during the Miocene. Conditions in the early Miocene are uncertain with cool-temperate mollusks mixed with warm-temperate and subtropical forms. The middle Miocene appears to reflect cool to mild-temperate conditions. In the early late Miocene increasing molluscan diversity and the presence of some subtropical exotic taxa indicate at least warm-temperate conditions. In the middle late Miocene there was a cooling event followed by increasing temperatures in the late late Miocene. This culminated in a warm-temperate/subtropical molluscan assemblage in the late Miocene. This warm period was followed by an abrupt cooling event, which carried on into the early Pliocene.

#### PLIOCENE

During the Pliocene, at least four marine transgressions are recorded in southeastern Virginia. The first, a limited, shallow-shelf, temperate-water deposit (Sunken Meadow Member, Yorktown Formation) (Figure 6C), occupied about half the areal extent of the Claremont Manor Member but also overlapped the Norfolk arch extending deep into the Albemarle embayment. A second, more extensive transgression took place in the early late Pliocene (Rushmere Member and Morgarts Beach Member) (Figure 6C). This pulse covered most of the Virginia Coastal Plain, overlapped the Norfolk arch and the Cape Fear arch, and extended as far south as the Southeast Georgia embayment on the Atlantic coast. Sediments deposited during this period within the Salisbury and Albemarle embayments have been termed the Rushmere and Morgarts Beach Members. A brief regression followed the Morgarts Beach but deposition resumed in the southeastern Virginia area with the shelly, bioclastic sands of the Moore House Member. This embayment was restricted to an area north of the Norfolk arch and south of the Piankatank River (Figure 6C). A final transgression during the late Pliocene was centered mainly in northeastern North Carolina but overlapped slightly into southeastern Virginia and resulted in the shelly sands of the Chowan River Formation (Figure 6D).

The moderately diverse early Pliocene molluscan assemblage suggest cool-temperate conditions. During the late Pliocene diversity increased with increasing

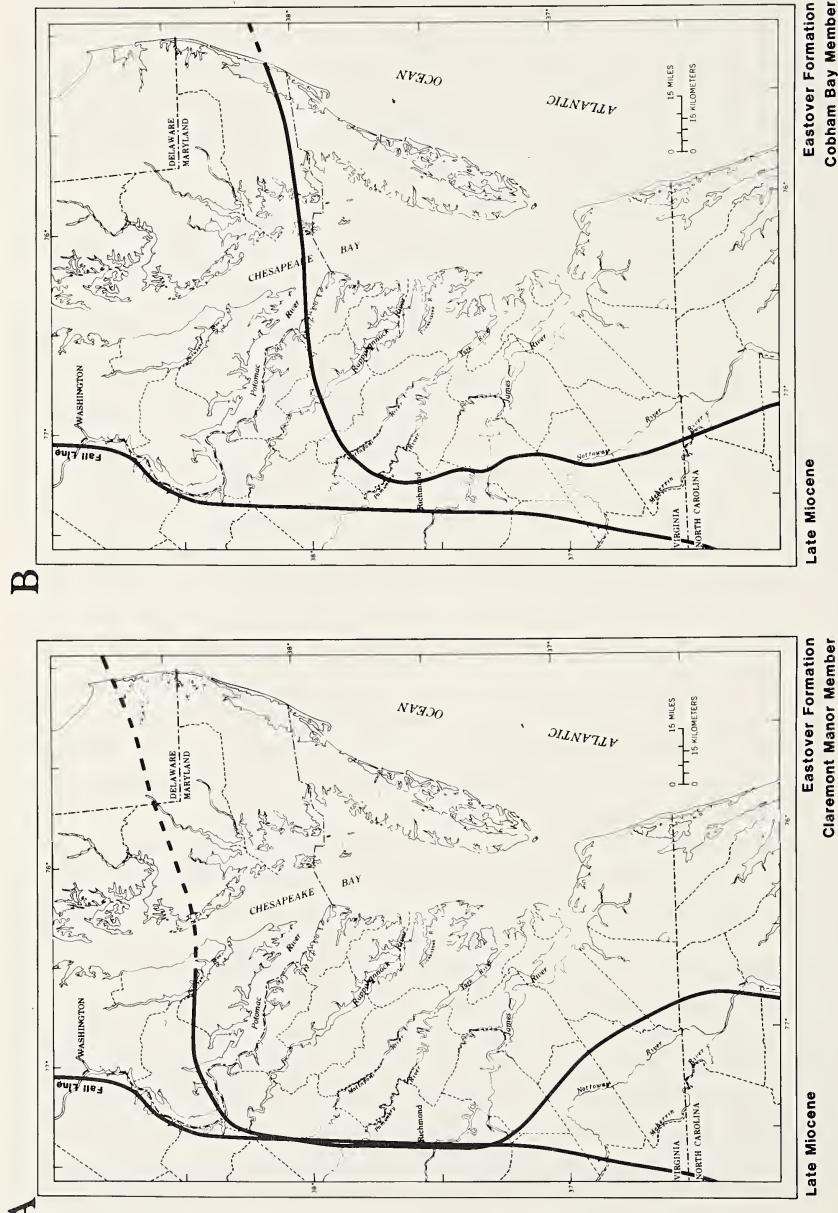
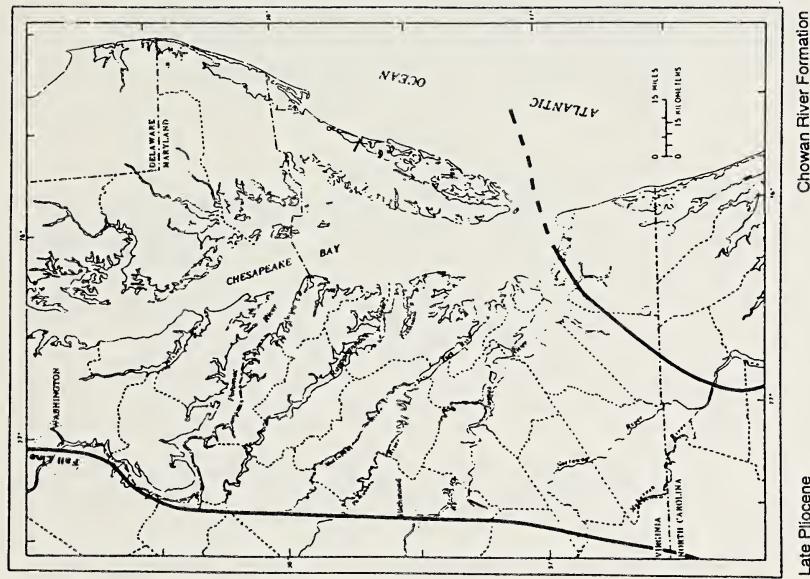


FIGURE 6A & B. Maps showing depositional basins from the late Miocene thru the late Pliocene. Dashed lines indicate areas where boundary data are lacking.

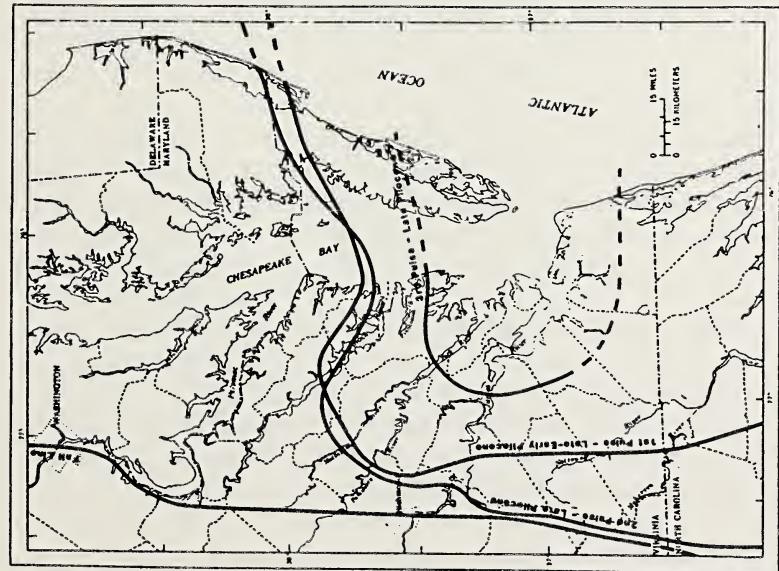
D



Late Pliocene

Chowan River Formation

C



Yorktown Formation

Early-Late Pliocene

FIGURE 6C & D. Maps showing depositional basins from the late Miocene thru the late Pliocene. Dashed lines indicate areas where boundary data are lacking.

temperatures. Mollusks in the upper part of the Yorktown Formation indicated warm-temperate to subtropical conditions. In the late Pliocene, at approximately 3.0-3.5 Ma, an abrupt lowering of sea level at the same time there was a severe cooling event produced a large-scale extinction event. This event decimated the temperate fauna, which had predominated since the late Oligocene. A subsequent warming during the late Pliocene (2.0 Ma) accompanied a transgression of the Salisbury embayment (Figure 6D), but many of the taxa so common there previously were missing. During the latest Pliocene and Pleistocene repeated severe cooling events entirely removed the temperate setting and fauna. Today boreal currents meet subtropical ones at the Cape Hatteras axis.

#### LITERATURE CITED

- Abbott, W. H. 1978. Correlation and zonation of Miocene strata along the Atlantic margin of North America using diatoms and silicoflagellates. *Marine Micropaleontology* 3: 15-34.
- Andrews, G. W. 1978. Marine diatom sequence in Miocene strata of the Chesapeake Bay region, Maryland. *Micropaleontology* 24: 371-406.
- Cushman, J. A., and D. J. Cederstrom. 1945. An upper Eocene foraminiferal faunal from deep wells in York County, Virginia. *Virginia Geological Survey, Bulletin* 67. 58 pp.
- Gernant, R. E. 1970. Paleoecology of the Choptank Formation (Miocene) of Maryland and Virginia. *Maryland Geological Survey Report of Investigations No. 12.* 90 pp.
- Shattuck, G. B. 1902. The Miocene Formations of Maryland. *Science* 15: 906.
- \_\_\_\_\_. 1904. Geological and paleontological relations, with a review of earlier investigations. *Maryland Geological Survey, Miocene Volume.* pp. 33-94.
- Vail, P. R., and R. M. Mitchum, Jr. 1979. Global cycles of relative changes of sea level from seismic stratigraphy. pp. 469-472 in *Geological and geophysical investigations of continental margins.* American Association of Petroleum Geologists, Memoir 29. .
- Ward, L. W. 1984. Stratigraphy and paleontology of the outcropping Tertiary beds along the Pamunkey River, central Virginia Coastal Plain. pp. 11-17; 240-280 *In Ward, L. W., and K. Krafft, eds. Stratigraphy and paleontology of the outcropping Tertiary beds in the Pamunkey River Region, central Virginia Coastal Plain.* Atlantic Coastal Plain Geological Association 1984 Field Trip Guidebook.
- \_\_\_\_\_. 1985. Stratigraphy and characteristic mollusks of the Pamunkey Group (lower Tertiary) and the Old Church Formation of the Chesapeake Group-Virginia Coastal Plain. *U.S. Geological Survey Professional Paper* 1346. 78 pp.
- \_\_\_\_\_, and B. W. Blackwelder. 1980. Stratigraphic revision of upper Miocene and lower Pliocene beds of Chesapeake Group, middle Atlantic Coastal Plain. *U.S. Geological Survey Bulletin* 1482-D. 61 pp.

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## Land-Use Changes in Southern Virginia Piedmont, 1917 to Present

Stanley R. Gemborys and Anne C. Lund

Department of Biology, Hampden-Sydney College,  
Hampden-Sydney, Virginia 23943

### ABSTRACT

We studied the changes in land-use and physiognomy that have taken place near Hampden-Sydney College in Prince Edward County, Virginia and in the Appomattox Court House National Historical Park in Appomattox County, Virginia. Information developed in this study is based on photo interpretation and measurements of aerial photographs supplied by the Soil Conservation Service of the United States Department of Agriculture. These photos were taken in 1937, 1949, 1972, and 1980 (Hampden-Sydney) and 1937, 1949, 1970, and 1984 (Appomattox). Based on the 1937 photographs and a knowledge of successional patterns, we were able to predict confidently the composition of stands in existence in 1917. Land uses have changed significantly. Forested land increased from about 33 to 77, and 28 to 53% coverage for Hampden-Sydney and Appomattox, respectively, between 1917 and the mid-1980's. There were corresponding decreases in open land.

**Key Words:** land-use history, plant succession, vegetation, Virginia Piedmont, landscape

### INTRODUCTION

There is an unfortunate tendency among both lay and professional people to view the landscape as a static and unchanging entity. Primary causative factors of this attitude may be the mobility of our society and the relative shortness of human life with respect to the time required for the appearance of changes in the composition of forest ecosystems. We know, intellectually, that plant communities are dynamic and changing entities but need to remind ourselves continually of this in order to understand their history and project their future development. Oosting's classic work (1942), extended by Odum (1959), described old field succession in the North Carolina Piedmont wherein abandoned field progressed to grass/shrub to young pine, older pine/hardwood mixture and finally to a stable hardwood community. We recognize the 100-150 year time scale associated with this sequence. We can readily accept these ecologists' abstract concepts and can observe the representative seral stages as they exist around us, but we often do not normally integrate the abstract and the concrete into an understanding of our contemporary landscape. Even among descriptive plant ecologists there is a primary emphasis on the contemporary community rather than its antecedents or its descendants (Gemborys, 1974).

But now, in a time of great environmental concern, with strong pressures coming from those who favor changes and pressures just as great coming from those who favor trying to maintain things as they are, it is essential that we recognize that these forests we now think of as "normal" were not even here 50 years ago and what we have now will, even without man's intervention, be quite different in another 50 years' time. We tend to believe, from reading the popular press, that all forests are being converted to housing developments and shopping centers and that soon all trees will have been made into newsprint. These concerns may be valid for some areas, but we don't think they are universally applicable. For example, one general indicator of the increase in woodlands in the Appomattox County/Prince Edward County southern Piedmont area is the increase in the volume of standing sawtimber in these counties between 1959 and 1985. In the years 1959, 1967, 1976, and 1985, there were sawtimber volumes for Appomattox and Prince Edward of 263 and 199; 310 and 231; 349 and 349; and 378 and 457 million board feet, respectively. Most of these increases were due to growth in hardwood volume and not in pine volume (Larson and Bryan, 1959; Knight and McClure, 1967; Sheffield, 1976; Brown, 1985).

The purpose of this work was to document, using evidence from a variety of sources, those changes in landscape appearance of typical southern Virginia Piedmont plant communities that have taken place over the last 50 years. The 2 localities selected for analysis were an 1800 acre tract centered on Hampden-Sydney College in Prince Edward County, and the 1325 acre Appomattox Court House National Historical Park, located in Appomattox County, Virginia. Both of these sites: (1) are believed to be representative of the ecosystems we normally find in the southern Piedmont; (2) have similar founding dates and agricultural histories; (3) demonstrate similar topography, soils, geology, and climate; (4) present a wide variety of habitats ranging from wet bottomlands to dry uplands; and (5) have been included regularly since 1937 in the aerial photography flown by the Soil Conservation Service of the United States Department of Agriculture. Moreover, because of the great historical importance of both sites, there existed the potential to gain access to relevant data and information collected incidentally by others over the years.

#### MATERIALS AND METHODS

We first obtained 22.9 cm square contact prints of aerial photographs of the 2 study areas from the U.S.D.A. Soil Conservation Service. The Appomattox Court House photos were taken in 1937, 1949, 1970, and 1984 and included prints numbered Sept 20 1937 FG 150 105 to 107 and 149 to 151; 9-9-49 DHD-4F-70 to 74; 9-9-49 DHD-3F-89 to 91; 10-4-70 DHD-2LL 43, 44, 72, and 73; and 4-11-84 513-66 377810 HAP 83 F. The Hampden-Sydney photos were taken in 1937, 1949, 1972, 1980 and included prints numbered JUL 24 1937 FG 139-34; 7-22-49 DHM-2F-77; 9-11-72 51147 272-88 and 89; and, 11-2-80 40 51147 279-5.

Next, through study and interpretation of the images presented on these photographs and by making checks of our categorizations in the field, we transferred information regarding several categories of vegetation type onto a series of base maps. Natural regeneration of pine included both Shortleaf Pine (*Pinus echinata* Mill.) and Virginia Pine (*Pinus virginiana* Mill.) but recently a few sites have been planted with Loblolly Pine (*Pinus taeda* L.). Our data do not differen-

tiate between these types. The "Hardwoods" category includes both upland and bottomland communities. White Oak (*Quercus alba* L.), Post Oak (*Quercus stellata* Wangenb.), Southern Red Oak (*Quercus falcata* Michx.) and Hickories (*Carya* spp.) dominate the upland forests. Yellow Poplar (*Liriodendron tulipifera* L.), Red Maple (*Acer rubrum* L.), Sycamore (*Platanus occidentalis* L.) and Blackgum (*Nyssa sylvatica* Marsh.) are commonly found in the bottomland forests. The Appomattox base map was developed from a map constructed by Hamilton (1985) and the Hampden-Sydney map was based on a recent Prince Edward County Tax Map. The major categories included, simply, "Open Land", "Young Pine", "Old Pine", "Hardwoods", and in the case of Hampden-Sydney, a category called "Campus". Then, using a Lasico Polar Compensating Planimeter, we determined the area and percentages for the various land-uses and vegetation types between 1937 and nearly contemporary times.

Given our familiarity with the concept of plant succession and the path it follows in the Piedmont, it seemed valid to carry our vegetation maps at least 20 years back in time, from 1937 to 1917. For, we know with fair certainty that a pine stand that appeared to be 20 years old in 1937 was probably an old field, recently abandoned, in 1917; that a pine stand that was 40 years old in 1937 was 20 years old in 1917; and that a mixed pine/hardwood stand that was present in our 1937 photograph would probably have been a 40 year old pine stand in 1917. We do recognize the small possibility that some forests may have been converted to agricultural use during the 1917 to 1937 period leading to an underrepresentation of the area of forested land in 1917.

## RESULTS

Figures 1 through 5 are the land-use maps developed for the 1800 acre Hampden-Sydney area for the period 1917 to 1980. In Figures 1 and 2 there is an area in the upper right corner of the map where no forest land is indicated. Unfortunately the 1937 photo does not have complete coverage, so this map, together with the 1917 map derived from it, presents no information regarding land-use of this area. This area was excluded when percentages of the various land-use coverages were calculated. Similar maps were developed for Appomattox Court House but are not represented here. Tables 1 and 2 and Figures 6 and 7 represent numerically and graphically the results derived from measurements made of the maps.

In the case of Hampden-Sydney there are 4 important trends apparent. First, is the continuous and steady decline in the percentage of open, agricultural land, from a maximum of 61% in 1917 to a low of 12% in 1980. Second, is the expansion followed by a decline in the percentage of young pine forest less than 20 years old during the study period. Young pine started at 7% in 1917, increased to a high of 25% in 1949, and then decreased to 1% in 1980. Third, is the recent expansion in the percentage of land covered by older pine forest. This category has shown a slow steady increase from 0 in 1917 to 20% in 1980. Fourth, is the steady increase in area occupied by hardwood stands during the period of study, from 26% in 1917 to 56% in 1980. These results are essentially consistent with Oosting's successional model, that of replacement of one community by another, especially in an area in which agriculture is declining in importance.

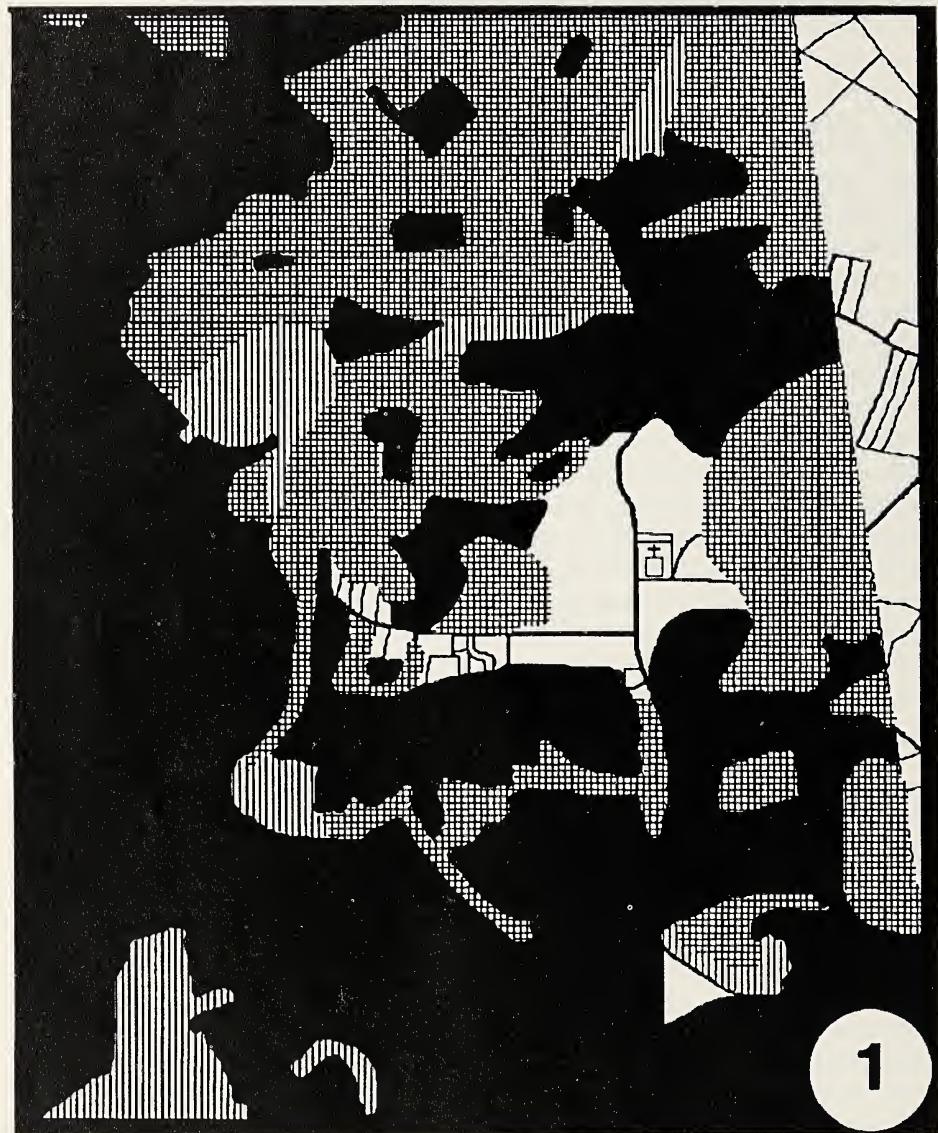


FIGURE 1. Map of probable land-use patterns in the Hampden-Sydney area, 1917. White, Campus and Local Settlements (except for upper right corner for which aerial photography was unavailable); black, Agricultural Lands; vertical lines, Pine Stands less than 20 years old; horizontal lines, Pine Stands greater than 20 years old; and, gridded lines, Hardwood Stands.

Land-use at Appomattox Court House, on the other hand, shows a quite different developmental pattern. First, the amount of open land showed a decline, from 72% in 1917 to around 50 in 1937, a figure near where it stands today. Second, young pine stands originally stood around 21% in 1917 but decreased to 5% percent in 1984. These young stands, evident in the 1984 photographs, represent planta-



FIGURE 2. Map of land-use patterns in the Hampden-Sydney area, 1937. White, Campus and Local Settlements (except for upper right corner for which aerial photography was unavailable); black, Agricultural Lands; vertical lines, Pine Stands less than 20 years old; horizontal lines, Pine Stands greater than 20 years old; and, gridded lines, Hardwood Stands.

tions, and not natural reproduction (Anonymous, 1977; Hamilton, 1985). Third, older pine stands showed an increase from none in 1917 and 1937 to 20% in 1984. Fourth, hardwood stands have remained steady at about 28%.

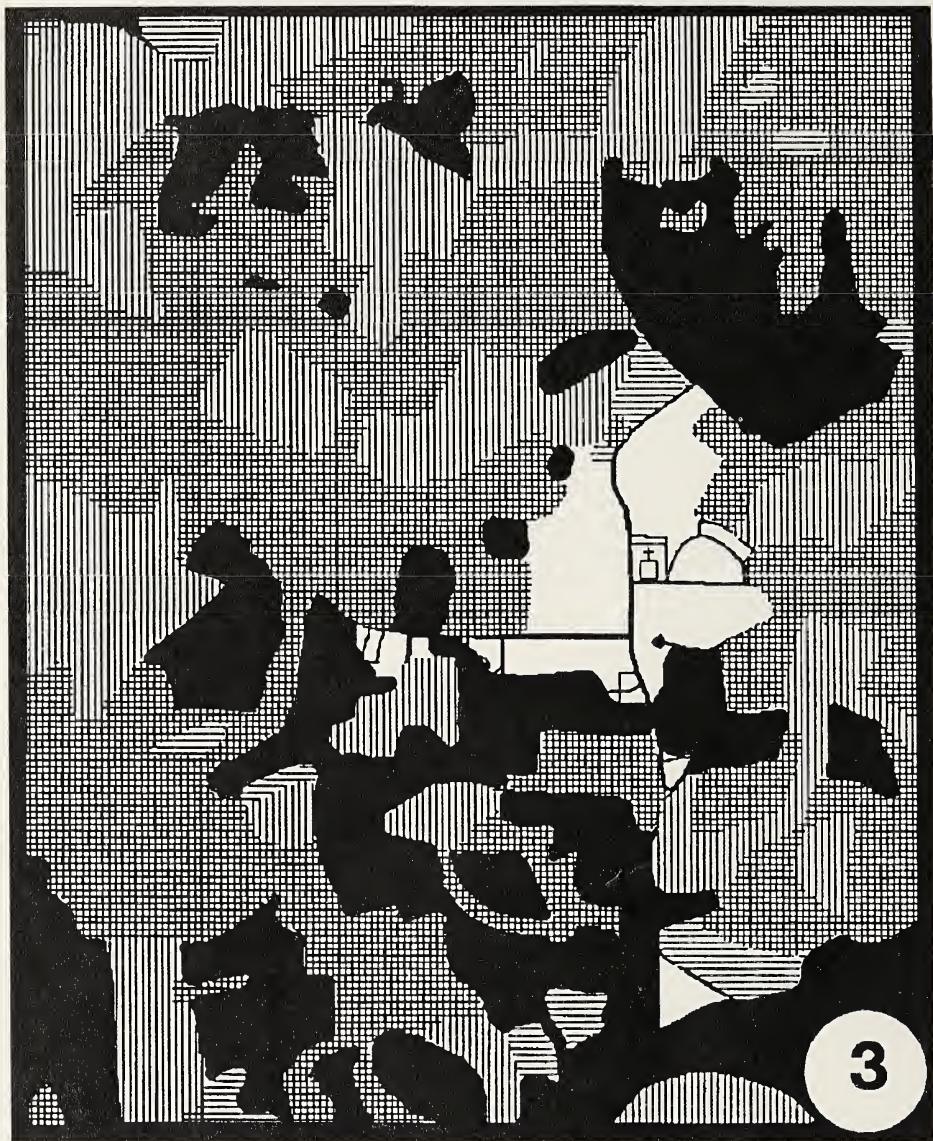


FIGURE 3. Map of land-use patterns in the Hampden-Sydney area, 1949. White, Campus and Local Settlements; black, Agricultural Lands; vertical lines, Pine Stands less than 20 years old; horizontal lines, Pine Stands greater than 20 years old; and, gridded lines, Hardwood Stands.

The primary differences between these 2 areas, Hampden-Sydney and Appomattox Court House, are that at Hampden-Sydney the percentages of open, agricultural land have decreased and hardwoods have increased, while at Appomattox both have remained relatively stable over the study period. We now know that the relative stability of the Appomattox site is the result of a conscious effort

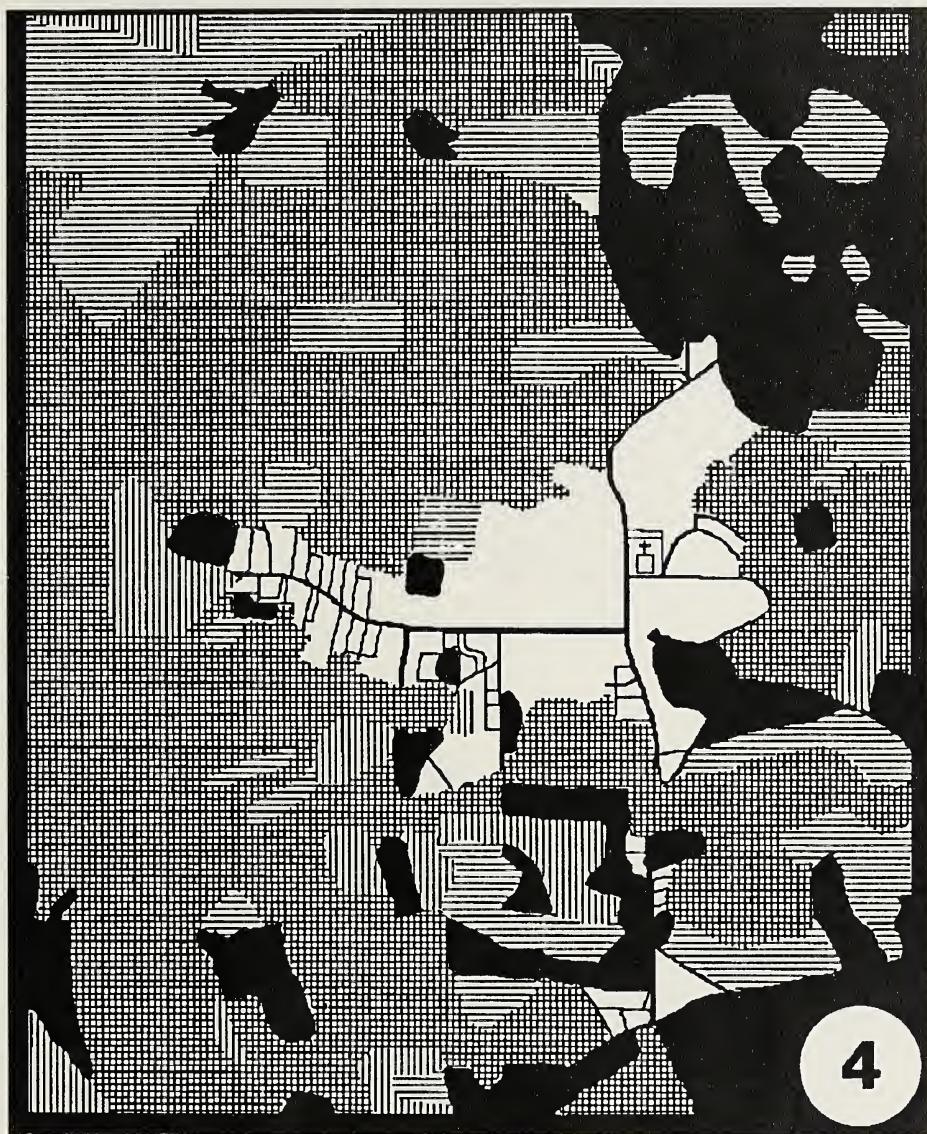


FIGURE 4. Map of land-use patterns in the Hampden-Sydney area, 1972. White, Campus and Local Settlements; black, Agricultural Lands; vertical lines, Pine Stands less than 20 years old; horizontal lines, Pine Stands greater than 20 years old; and, gridded lines, Hardwood Stands.

by the park staff to maintain the site's appearance "as it was at the time of the war", combined with a major effort to create a visual barrier around the boundaries of the park in order to prevent the intrusion of modern distractions (Anonymous, 1977; Montgomery, personal communication).

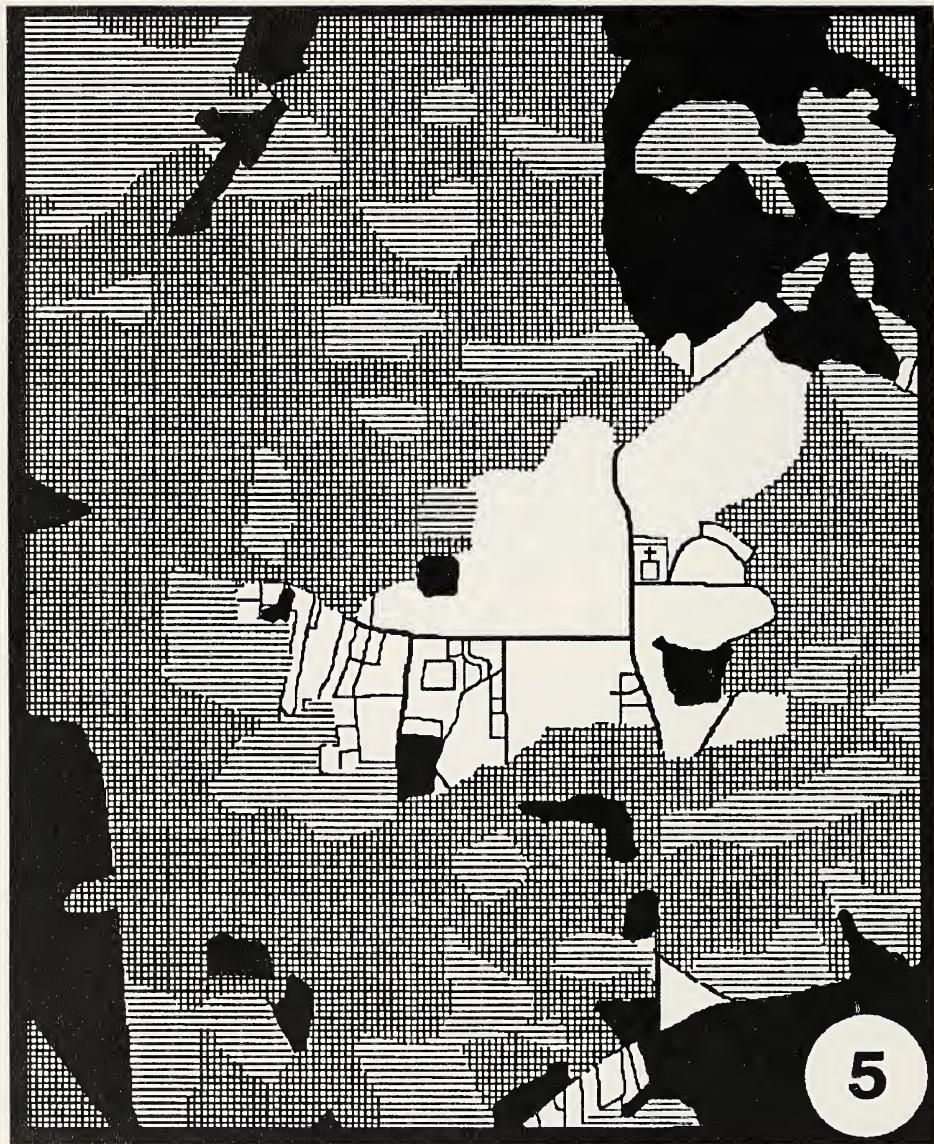


FIGURE 5. Map of land-use patterns in the Hampden-Sydney area, 1980. White, Campus and Local Settlements; black, Agricultural Lands; vertical lines, Pine Stands less than 20 years old; horizontal lines, Pine Stands greater than 20 years old; and, gridded lines, Hardwood Stands.

#### DISCUSSION

Our work has demonstrated that major changes in the landscape have occurred in at least the last 70 years in the southern Virginia Piedmont. We expect that, unless active efforts are made to preserve the current mix of plant communities, as currently is being done aggressively at Appomattox, changes will inevitably con-

TABLE 1. Percent of area covered by Campus or Local Settlements, Open Land, Pine Stands less than 20 years old, Pine Stands more than 20 years old, and Hardwood Stands in a 2.8 square mile area centered on Hampden-Sydney College, Prince Edward County, Virginia for the years 1917, 1937, 1849, 1972, and 1980. The apportionment of percentage during the latter 4 years is based on an interpretation of photographs supplied by the United States Department of Agriculture Soil Conservation Service. The percentages given for the 1917 time period represent an extrapolation based on the 1937 data.

LAND USE	YEAR				
	1917	1937	1949	1972	1980
Campus, Local Settlements	6	6	7	12	12
Open Land	61	35	24	12	12
Pine Stands less than 20 Years Old	7	24	25	5	1
Pine Stands more than 20 Years Old	0	7	3	17	20
Hardwood Stands	26	28	43	53	56

TABLE 2. Percent of area covered by Open Land, Pine Stands less than 30 years old, Pine Stands more than 30 years old, and Hardwood Stands in the 1325 acre Appomattox Court House National Historical Park, Appomattox County, Virginia for the years 1917, 1937, 1949, 1970 and 1984. The apportionment of percentage during the latter 4 years is based on an interpretation of photographs supplied by the United States Department of Agriculture Soil Conservation Service. The percentages given for the 1917 time period represent an extrapolation based on the 1937 data.

LAND USE	YEAR				
	1917	1937	1949	1970	1984
Open Land	72	50	50	46	47
Pine Stands less than 30 years old	21	23	18	7	5
Pine Stands more than 30 years old	0	0	6	19	20
Hardwood Stands	7	26	26	29	28

tinue, with predicted increases in hardwood forests and decreases in open land and pine stands. It is even questionable whether the conversion of hardwood forests to commercial pine monocultures can reverse this trend.

It is also important to recognize that the ecosystems of our 1917 starting point, which were essentially dominated by open fields, were vastly different from those encountered by the early white settlers and that our contemporary forest ecosystems are perhaps more like those of the primeval forest than at any time since the settlers' arrival. We speculate that the Piedmont may be regaining its original appearance (albeit with species changes) while other areas of the state, such as Tidewater and Northern Virginia, are undergoing community destruction on a major scale.

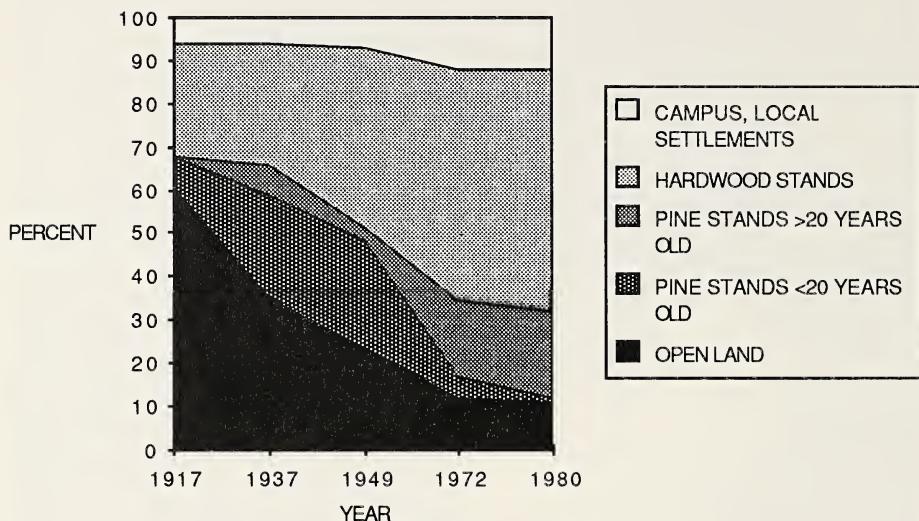


FIGURE 6. Percent of area representing different land-uses, 1917 through 1980, Hampden-Sydney.

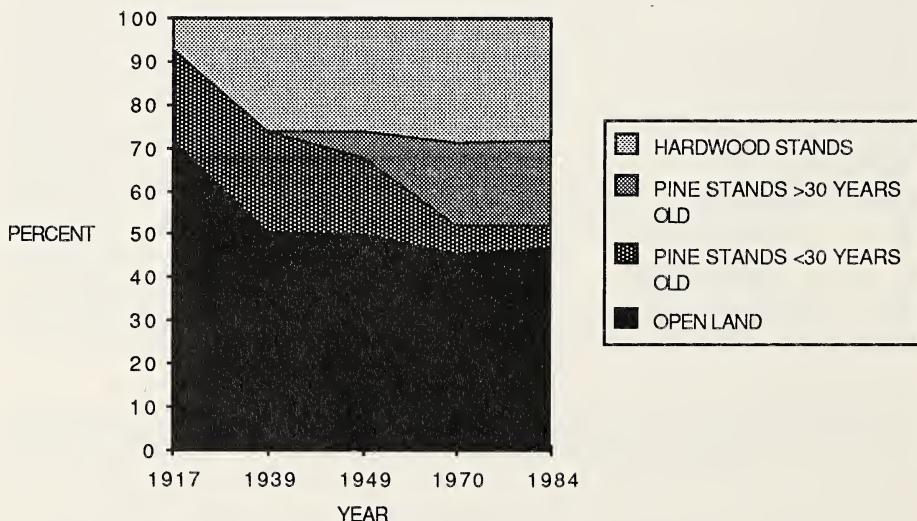


FIGURE 7. Percent of area representing different land-uses, 1917 through 1984, Appomattox Court House National Historical Park.

Certainly our work demonstrates, in a small way, that deciduous forest ecosystems are tremendously resilient, at least in terms of gross appearance, and can reestablish themselves in a relatively short period of time. But, the short time span over which these hardwood communities, in particular, have been reassembled brings into question the degree of stability that they may have attained. Many are concerned with the extent of the development of commercial pine monocultures. We wonder if our concern with the monocultures is overstated when we reflect on the history of the areas we studied and take into consideration the historical development of natural pine stands and the great increase in hardwoods. We emphasize that our results are representative of conditions in a relatively small area of the state and may not apply in zones more urban or more agriculturally prosperous.

#### ACKNOWLEDGMENTS

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#### LITERATURE CITED

- Anonymous. 1977. General Management Plan: Appomattox Court House National Historical Park, Virginia. United States Department of the Interior, National Park Serv., Washington, DC. 140 pp.
- Brown, M. J. 1985. Forest statistics for the southern Virginia Piedmont, 1985. United States Department of Agriculture, Forest Service Resource Bulletin SE-81. Southeastern Forest Experimental Station, Asheville, North Carolina. 55 pp.
- Gemborys, S. R. 1974. The structure of hardwood forests of Prince Edward County, Virginia. *Ecology* 55:614-621.
- Hamilton, S. C. 1985. Forest management plan for the Appomattox Court House National Historical Park. Unpublished M.S. Thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 160 pp.
- Knight, H. A. and J. P. McClure. 1967. Virginia's Timber, 1966. United States Department of Agricultural, Forest Service Resource Bulletin SE-8. Southeastern Forest Experimental Station, Asheville, North Carolina. 47 pp.
- Larson, R. W. and M. B. Bryan. 1959. Virginia's Timber. United States Department of Agriculture Forest Service Survey Release #54. Southeastern Forest Experimental Station, Asheville, North Carolina. 73 pp.
- Odum, E. P. 1959. Fundamentals of Ecology. 2nd ed. W. B. Saunders and Co., Philadelphia. 546 pp.
- Oosting, H. J. 1942. An ecological analysis of the plant communities of Piedmont, North Carolina. *American Midland Naturalist*. 28:1-126.
- Sheffield, R. M. 1976. Forest statistics for the southern Piedmont of Virginia, 1976. United States Department of Agriculture Forest Service Resource Bulletin. SE-35. Southeastern Forest Experimental Station, Asheville, North Carolina. 35 pp.



## Historic Trends in Wetland Protection in the State of Virginia

Harold J. Wiggins<sup>1</sup>, U.S. Army Corps of Engineers,  
Norfolk District, Fredericksburg Field Office  
10703 Courthouse Road, Suite 270  
Fredericksburg, Virginia 22407

### ABSTRACT

Recent Virginia state legislation involving inland non-tidal wetland areas brings greater coordination among federal, state and local jurisdictions. The Chesapeake Bay Preservation Act of 1988, as mandated by state law, compels local planning departments to recognize and identify non-tidal wetland areas as Resource Protection Areas and Resource Management Areas. The Virginia State Water Control Board has recently asserted its certification of authority for discharges exceeding 1 acre in headwater and isolated waters. As a result of an interagency agreement wetland areas can be assessed and delineated to concur with a unified definition. The 1989 Federal Manual for Identifying and Delineating Jurisdictional Wetlands has brought greater federal regulation to wetland habitats in Virginia. Palustrine, forested, broad leafed, seasonally saturated wetlands have received greater protection as a result of the unified federal definition. The Norfolk district of the Army Corps of Engineers has opened 4 new field offices in Virginia in early 1991. Greater Corps involvement with more field offices will serve to minimize and regulate wetland losses.

**Key Words:** wetlands, regulation, protection, legislation, marshes

### INTRODUCTION

The values of wetland ecosystems have been, and continue to be, documented by a growing body of research and literature. Many authors recognize the significant ecological, economic, recreational, and aesthetic values and functions of wetlands (Teal and Teal, 1969; Gossellink, et al., 1974; Larson, 1982; Tiner, 1984). Because of the many benefits that these wetlands provide, the federal government and the state of Virginia have enacted legislation providing wetland protection through the regulation of activities that have an impact on them. The cornerstone to wetland protection in conjunction with federal and state laws is the availability of a technical wetland definition. This allows regulators a consistent set of criteria for delineating wetland boundaries when making permit or enforcement decisions.

### CHRONOLOGY OF EVENTS

The state of Virginia has regulated activities in its tidal wetlands primarily through its Wetlands Act of 1972 (Code of Virginia 62.1 chapter 2.1 1972). The

<sup>1</sup> The views expressed in this paper are the writer's own and do not necessarily represent the views of the U.S. Army Corps of Engineers or any other regulatory agency involved in wetland protection.

historical evolution of Virginia's legal code protecting subaqueous bottoms began with the formation of the Virginia Marine Resources Commission (VMRC). VMRC's jurisdiction is based on the Commonwealth's title. Since the Commonwealth has title unless it has been lawfully conveyed, VMRC should presume that it has jurisdiction over any subaqueous bed in the Commonwealth until someone else shows title to the bed derived from a grant from the King or the Commonwealth. The manner in which such title would have been granted depends on the date at which the grant was made, and whether the waterway is navigable or non-navigable.

The Virginia Wetlands/Virginia Marine Resource Commission (VMRC)/Code of Virginia, Section 62.1 and Chapter 2.1 placed the Virginia Institute of Marine Science (VIMS) and local wetlands boards for each locality in the review process. VMRC regulates activities (structures, dredging and filling) occurring between mean low water and mean low water, or in other words all tidal subaqueous bottom. With the enactment of Chapter 300 Acts of Assembly, 1982, amendments to existing wetlands protection mechanisms would now include nonvegetated intertidal flats and beaches, as well as interrelated and interdependent functions of the vegetated and nonvegetated wetland ecosystems. Code of Virginia 62.1-13.5 allows counties, cities and towns authority to adopt wetlands zoning ordinances. Local wetlands boards regulate wetland areas which are defined by the Commonwealth of Virginia (Code of Virginia, 1972) as:

Vegetated Wetlands: "include the land lying between and contiguous to mean low water to an elevation above mean low water equal to 1.5 times the mean tide range at the site of the proposed project and upon which one or more species of tidal wetlands plants is growing".

Nonvegetated wetlands: "include the land lying between and contiguous to mean low water to an elevation of mean high water not otherwise considered "vegetated wetlands".

Additional definitions which define VMRC's jurisdiction include "Navigability-in-Fact" (Code of Virginia, 1972). VMRC may assume jurisdiction unless the landowner can show title to riparian land acquired by grant prior to July 4, 1776. In the case of "Non-Navigable-in-Fact", VMRC may assume jurisdiction unless the landowner can show a grant prior to 1792 in that part of the state draining toward the Atlantic Ocean, or prior to 1802 in that part of the State draining toward the Gulf of Mexico.

VMRC's jurisdiction is based on the Commonwealth's ownership of the bottom, and the Commission should assume that unless as otherwise outlined above, the Commonwealth no longer has title to the parcel in question.

The responsibility for regulating non-tidal wetland areas in the state such as palustrine forested wetlands, was primarily authorized by the Federal Pollution Control Act of 1972. Although this Act began as an attempt to regulate discharges into tidal waterways (navigable waters), the extent of the jurisdiction of the Act reached into non-tidal areas as well. This act was later amended to the Clean Water Act (CWA) of 1972. The CWA, as amended, provided for State Water Quality Certification (Section 401) and required permits for the "discharge of dredged or fill materials into waters of the United States". Thus, the Clean Water Act regulated those activities which have an impact on wetlands. A technical definition of the

term "wetland" was not available to state and federal regulators, as adjacent wetlands were generally considered tidal or freshwater marsh. A general definition is provided in Section 328.3 (a)(b) of the Clean Water act:

The term "wetlands" means those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas (Federal Register, 1986).

This definition recognized 3 fundamental qualities of all wetlands; 1.) wetland plants, 2.) wetland soils and, 3.) wetland hydrology. Although the broad and general definition of wetland was provided in the Clean Water Act, the methods for identifying non-tidal wetland areas in the state varied widely. Due to the spectrum of moisture regimes and plants that occur in varying degrees of soil saturation during the growing season of the year, any attempt by regulatory agencies to delineate wetlands often led to confusion, disagreement and indecision. This situation was exacerbated by the creation of "several" regulatory definitions developed by each agency of the federal government. The U.S. Army Corps of Engineers, The U.S. Fish and Wildlife Service, the U.S. Environmental Protection Agency and the U.S. Soil Conservation Service were each equipped with their own regulatory definitions of what constituted a wetland. These agencies used their own technical manuals which provided criteria based on soil types, plant associations and hydrologic characteristics which may be present on a site. Based on these technical criteria, the agencies were allowed to delineate transitional areas between temporarily inundated and upland areas. The wetlands that would fit these various regulatory definitions would gain protection as they were now under the jurisdiction of the various agencies. Although the various federal and state regulatory agencies couldn't always agree where the wetland/upland boundary occurred, a shift could clearly be seen in wetland protection in the state as wetland area that is considered non-tidal, and which lay west of Interstate 95 was brought under federal and state jurisdiction. The problem that existed with the enforcement of the Clean Water Act was partly based on the disagreement between the federal agencies as to the precise wetland definition that each based their decision on for identifying the technical criteria of wetland. Wetland protection in the state of Virginia is partially a function of the availability of a unified definition of "wetland" that would allow regulators to enforce the Clean Water Act and other wetland protection acts such as the Food Security Act of 1985.

In January of 1989, the *Federal Manual for Identifying and Delineating Jurisdictional Wetlands* was issued. The 4 federal agencies of the federal government, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service and the U.S. Soil Conservation Service each combined their technical manuals into one. The unified federal manual was the cumulation of efforts to merge existing field-tested wetland delineation manuals, methods, and procedures used by these agencies. The 1989 Federal Manual not only unified the interagency definition, it also brought vast non-tidal wetland areas along the coastal plain and inland areas of the state under federal and state regulation. Non-tidal wetlands are the subset of the wetland resources that lie upstream of tidally influenced waters. They represent the majority of the Mid-Atlantic region's wet-

lands and include freshwater marshes, wet meadows, bogs, shrub swamps, bottom-land hardwood forests, shallow ponds, seepage areas, and springs. They range in size from small isolated depressions surrounded by upland to large complexes thousands of hectares in size on the floodplains of major rivers (Tiner 1988).

The 1989 manual defined a "three parameter approach" to wetland identification: *hydric soils*, *hydrophytic vegetation* and *wetland hydrology*. The technical definition of hydric soil is as follows: a soil that is saturated, flooded or ponded long enough during the growing season to develop anaerobic conditions in the upper part (U.S.D.A. Soil Conservation Service 1987). In general, hydric soils are flooded, ponded, or saturated for usually 1 week or more during the period when soil temperatures are above biologic zero. This is defined as 5 degrees centigrade by "Soil Taxonomy" U.S.D.A. Soil Survey Staff 1975. These soils usually support hydrophytic vegetation.

The technical definition of hydrophytic vegetation is as follows: plant life growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content. The U.S. Fish and Wildlife Service in cooperation with the U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, and U.S. Soil Conservation Service has published the "National List of Plant Species That Occur in Wetlands". This list was developed from a review of the scientific literature which was further reviewed by wetland experts and botanists (Reed 1988). The list separates vascular plants into four basic groups, each with a "wetland indicator status". It is based on a plant species' frequency of occurrence in wetlands and includes the following: (1) obligate wetland plants (OBL) that occur almost always (estimated probability 99%) in wetlands under natural conditions; (2) facultative wetland plants (FACW) that usually occur in wetlands (estimated probability 67-99%), but occasionally are found in non-wetlands; (3) facultative plants (FAC) that are equally likely to occur in wetlands or non-wetlands (estimated probability 34-66%); and (4) facultative upland plants (FACU) that usually occur in non-wetlands (estimated probability 67-99%), but occasionally are found in wetlands (estimated probability 1-33%). If a species occurs almost always (estimated probability 99% in non-wetlands under natural conditions, it is considered an obligate upland plant (UPL). These latter plants do not usually appear on the wetland plant list; they are listed only when found in wetlands with a higher probability in 1 region of the country. If a species is not on the list, it is presumed to be an obligate upland plant.

The driving force behind the formation of wetland is, of course, water. A technical definition for wetland hydrology is provided in the Federal Manual of 1989: permanent or periodic inundation, or soil saturation for a significant period (usually a week or more) during the growing season. Based on the identification of hydrologic indicators in the field such as water stained leaves, wetland drainage patterns, morphological plant adaptations and hydric soils, the 7 consecutive days of inundation or soil saturation within the upper part of the soil could be deduced at the time these indicators were noted. The field scientist or professional observer typically identified emergent or palustrine wetland area as a condition where facultative (FAC), facultative wetland (FACW) and obligate wetland (OBL) vegetation was present on undrained hydric soils.

In September of 1990, the Chesapeake Bay Preservation Act of 1988/ Sections 10.1-2103 and 10.1-2107 of Chapter 21, Title 10.1 of the Code of Virginia came into effect for tidewater Virginia. The Act requires that 46 cities, counties and towns of tidewater Virginia amend their land use plans and ordinances to meet state standards for the protection of water quality. The aim of the legislation was to protect the water quality of the Chesapeake Bay. The legislation contained state standards for water quality protection which also included, for the first time, a state requirement for those localities within the Bay Act to identify their non-tidal wetlands.

The requirements of the Bay Act included Resource Protection Areas (RPAs) and Resource Management Areas (RMAs). Both land-use overlay areas include protection to jurisdictional (federally defined) wetland area. Wetland area adjacent to perennial stream may have a 100 foot buffer placed landward from the boundary of the wetland. Several local governments are presently requiring wetland assessments/delineations for compliance with Bay Act regulations. As provided in the Bay Act, in 1992 Virginia must review its progress under the 1987 Chesapeake Bay agreement with Maryland, Pennsylvania, the District of Columbia, and federal agencies.

Concurrent with the Bay Act legislation in 1990, the Virginia State Water Control Board asserted its 401 certification of authority in August of 1990 to regulate discharges into wetlands exceeding 1 acre (.4 hectare) in headwaters and isolated waters. As mandated by the Clean Water Act, the Corps of Engineers must have 401 certification, denial or waiver before Pre-Discharge Notification procedures can begin for these discharges. A Pre-Discharge Notification is provided to the Corps of Engineers for review when discharges of dredged or fill material which will cause the loss or substantial adverse modification of 1 to 10 acres (0.4 -4 hectares) of waters of the United States including wetlands (located above the headwaters) [( 33 CFR 330.5 (a)(26)) 1986]. The assertion of 401 certification by the state into areas that were not previously scrutinized by state regulators allowed the state great permit authority over wetland losses in the Commonwealth.

The Federal Manual of 1989 broadened the Corps jurisdiction and regulation of federally defined wetland areas to include areas that were typically ignored or not previously considered within Corps jurisdiction. Areas that need only be inundated or saturated with groundwater for a period of 1 week or more during the growing season (frost line to frost line) may be considered wetland under the new definition. Vast areas along the floodplains of rivers and streams were brought into federal regulation. Poorly draining farmland was brought under the Corps jurisdiction. Large parcels of land with poor drainage, due to neglected maintenance of drainage culverts were now protected by federal law.

On 17 August 1991, President Bush signed into law the Energy and Water Development Appropriations Act of 1992. The Act contained an amendment to the Corps regulatory appropriation that affects the use of the *Federal Manual for Identifying and Delineating Jurisdictional Wetlands* (1989 Manual). According to the federal lawmakers, the 1989 Manual was not adopted in accordance with the requirements for notice and public comment of the rule-making process of the Administrative Procedures Act. Since 17 August 1991, the Corps has utilized the *Corps of Engineers Wetlands Delineation Manual* (1987 Corps Manual). This

manual is less encompassing than the 1989 Manual, since the presumption that hydric soils are an indicator of wetland hydrology is not used in this manual. The inundation or saturation of the soil must be present for a minimum of 12.5 % of the growing season, as opposed to 7 days out of the growing season for the 1989 Manual.

The vegetation criteria for the 1987 Manual also require that FAC, FACW or OBL plant species dominate the vegetation strata, as opposed to FACU, FAC, FACW and OBL plant species included for a wetland determination for the plant criteria as in the 1989 Manual. This shift in manual use shrinks the jurisdiction of wetland areas, especially the palustrine forested wetland areas that are typically found along the floodplains of perennial streams.

On 15 August 1991, Proposed Revisions to the Federal Manual for Identifying and delineating Jurisdictional Wetlands were published in the FEDERAL REGISTER of the United States congressional record for public comment. This proposed manual was developed in response to concerns that the 1989 Manual may have included substantial area (based on 7 days of wetness) as wetland that may not be "wet enough" to be wetland. The hydrological criteria defined in the new manual requires that an area experience inundation for a minimum of 14 consecutive days or saturation to the surface for a minimum of 21 consecutive days. Also, greater scrutiny of plant dominance on a site is mandatory in this proposed manual.

State protection of wetland areas within the jurisdiction of the Chesapeake Bay Act has met with less than total compliance on the part of localities and land owners. Land developers have challenged the state's Bay Act with litigation. In 1 of 3 Bay Act suits filed by the same attorney in 1990, a York County Circuit Court judge threw out the Bay rules, delaying full implementation of the Act until late 1991. The Bay Act rules were challenged in court in York and Spotsylvania counties. Although 46 cities, counties and towns in Virginia are required to implement local ordinances of the Bay Act, only 32 Eastern Virginia cities and counties have bay regulations on their books to date.

## DISCUSSION

### **Current Status of Wetlands: A Regional Overview:**

In a comparison among Delaware, Maryland, Pennsylvania, Virginia and West Virginia, among the five states, Virginia has the greatest wetland acreage while West Virginia has the least. Virginia has approximately 739,600 hectares of wetland of which 301,080 hectares are inland vegetated wetlands. The remaining area of wetland is comprised of coastal vegetated wetlands, tidal flats/beaches, and freshwater ponds (Dahl, 1990).

It is estimated that in the 1780's, 1,050,200 hectares of wetlands existed in Virginia. Since that time, approximately 42% of the original wetlands have been lost in the State. Due to the historical perception of wetland as "wasteland" or a convenient place to dump trash and other debris, the Commonwealth has lost almost half of its original wetland area. As the many benefits of wetlands have become realized, this public resource has recently gained federal and state protection. State and federal laws have evolved in an attempt to preserve these sensitive areas. The intrinsic nature of these transitional areas to be dynamic and not static, makes technical definitions difficult and impermanent. This is further complicated

by the fact that any legal/technical definition must include the support of scientific, political and environmental communities.

#### LITERATURE CITED

- Code of Virginia. 1989. Laws of Virginia Relating to the Marine Resources of the Commonwealth, Reprinted from the Code of Virginia of 1950 and the 1989 Cumulative Supplement. The Michie Company, Charlottesville, Virginia. 57 pp.
- Dahl, T.E. 1990. Wetland Losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 21 pp.
- Environmental Laboratory. 1987. "Corps of Engineers Wetlands Delineation Manual," Technical Report Y-87-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss. 100 pp. + appendices
- Federal Interagency Committee for Wetland Delineation. 1989. Federal Manual for Identifying and Delineating Jurisdictional Wetlands. U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and U.S.D.A. Soil Conservation Service, Washington, D.C. Cooperative technical publication. 76 pp. + appendices.
- Federal Register. Part II. Department of Defense. Corps of Engineers, Department of the Army. 33 CFR Parts 320 through 330 Regulatory Programs of the Corps of Engineers; Final Rule. November 13, 1986. 54 pp.
- Federal Register. August 15, 1991. 1989 "Federal Manual for Identifying and Delineating Jurisdictional Wetlands"; Proposed Revisions. 106 pp.
- Gosselink, J.G., E.P. Odum, and R.M. Pope, 1974. The Value of the Tidal Marsh. Center for Wetland Resources, Louisiana State University, Baton Rouge. 30 pp.
- Larson, J.S., 1982. Wetland Value Assessment-State of the Art. Pages 417-424 in Gopal, Brij, R.E. Turner, R.G. Wetzel, and D.F. Wigham, eds. Wetlands Ecology and Management. Lucknow Publishing House, Lucknow, India.
- Reed, P.B., Jr. 1988. National list of plant species that occur in wetlands: Northeast (Region 1). U.S. Fish and Wildlife Service. Biology Representative 88(26.1). 111 pp.
- Teal, J.M., and M. Teal, 1969. Life and Death of the Salt Marsh. Boston: Little, Brown & Company. 274 pp.
- Tiner, R.W., Jr., 1984. Wetlands of the United States: Current Status and Recent Trends. U.S. Fish and Wildlife Service, National Wetlands Inventory, Washington, D.C. 59 pp.
- Tiner, R.W., Jr. 1988. Field Guide to Nontidal Wetland Identification. Maryland Department of Natural Resources, Annapolis, MD and U.S. Fish and Wildlife Service, Newton Corner, MA. Cooperative publication, 283 pp. + plates.



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## The Impact of Human Activities on the Upland Forests of Western Virginia

Steven L. Stephenson, Department of Biology,

Fairmont State College, Fairmont, West Virginia 26554

Harold S. Adams, Division of Science and Mathematics,

Dabney S. Lancaster Community College,

Clifton Forge, Virginia 24422

Michael L. Lipford, Virginia Department of Conservation

and Recreation, Division of Natural Heritage

Richmond, Virginia 23219

### ABSTRACT

Forest communities dominated by such species as red oak (*Quercus rubra*), chestnut oak (*Q. prinus*), white oak (*Q. alba*), and red maple (*Acer rubrum*) still cover large areas in the mountains of western Virginia. Although various human activities (e.g., lumbering operations, fires, and the clearing of land for agriculture) have had an impact upon these forest communities, the very limited data available from surveyor's records and other early accounts at least suggest that present-day forests are compositionally fairly similar to presettlement forests. Indeed, the most important change in composition that seems to have occurred is the almost complete elimination (at least from the forest canopy) of the American chestnut (*Castanea dentata*) by the chestnut blight. Prior to the blight, which was introduced into North America at the beginning of this century, chestnut was one of the most abundant trees in the upland forests of the mid-Appalachians. However, the potential for even greater change would seem to exist as a result of the spread of the gypsy moth (*Lymantria dispar*) into western Virginia, since oaks are among the tree species most susceptible to defoliation by this introduced insect pest.

Key Words: Forests, vegetation, Virginia, oaks, *Quercus*, perturbation, logging, agriculture, fire, gypsy moth, chestnut blight

### INTRODUCTION

"From the Atlantic to well beyond the Mississippi, and covering all the south, stretched an almost unbroken primeval forest. A squirrel might leap from bough to bough for a distance of a thousand miles and see scarcely a flicker of sunlight on the ground, so continuous were the tree crowns and so dense the foliage" (Chase, 1936).

Virginia's landscape, altered by millennia of environmental changes and natural perturbations and extensively modified by the Indians in pre-colonial times, was characterized as a diverse mosaic of forest communities when the Europeans began settlement. The Commonwealth's present landscape represents over 200 years of change and modification by an ever increasing human population. In the eastern

and central portions of the state, forests have been significantly altered by conversion to agricultural land, a process that dates from colonial times, and to urban areas, a process that has become increasingly more important in modern times.

Except for a few fragments of mostly bottomland hardwoods, the forest acreage that exists today is highly disturbed or heavily managed. However, in the more mountainous western portion of Virginia, large areas of forest still exist, most of which are in public ownership. Although a number of historical and economic factors were involved, the major reason these forests escaped destruction is simply because the land they occupy is not suitable for agriculture.

Although forests still cover large areas in the mountains of western Virginia, it does not necessarily follow that these forests are identical to or even fairly similar in composition to the original virgin forests as the first settlers found them. There is very little doubt that various human activities have had some impact upon these forest communities. The purpose of this paper is first to describe, using the rather limited data that are available, presettlement forest conditions in western Virginia and then to discuss some of the ways in which these forests have been affected by various human activities, including such things as the clearing of land for agriculture, fire, logging operations, and the inadvertent introduction of biotic agents destructive to specific tree species. Nomenclature used herein follows that of Radford et al. (1968).

#### EARLY ACCOUNTS OF FOREST COMPOSITION

Very little is known about the original forests of western Virginia, since relatively little quantitative data or even fairly detailed first-hand descriptions are available. However, the early survey records found in the archives of county courthouses often contain a surprising amount of information that can be used by ecologists (Spurr, 1951) and archeologists (Holland, 1980). Surveyors recorded names of trees encountered on survey perimeters (property lines) and at points where line direction changed. The metes-and-bounds (metes = bearings and distances; bounds = adjoiners) method was employed for measuring boundary lines in Virginia, the other 12 original colonies (which at that time included both Tennessee and Kentucky), and Texas (Stewart, 1935). Surveyors followed "natural" landmarks (e.g., rivers) rather than "straight" lines in establishing property boundaries. Sometimes descriptions were quite unusual (e.g., "Beginning at the old crow's nest on the north fork of the Kentucky..."). Understandably, questions of bias and inaccuracy arise in these kinds of data (Bourdo, 1956). Surveyors may have misidentified species or prejudicially selected only certain species (due to their known long-lived nature, their size, or their age). Nevertheless, these early survey records do provide an available source of information about the kinds of trees (and, presumably, their relative abundance) that existed in surveyed areas in the past. If this information seems reasonable in terms of present composition and known distribution for the tree species, one can have more confidence in the data.

We obtained data from the records of 50 original surveys (for the period 1823-1824) performed on warranted lands that were public domain in Allegheny County, Virginia (Lipford et al., 1985). Descriptions were read from original survey books retained at the county courthouse in the city of Covington. Each time a kind of tree was mentioned, this fact was recorded along with any additional information

such as size of tree or its habitat (e.g., by a stream, on a ridge). A total of 39 kinds of trees was recorded. This certainly would suggest that these surveyors were very knowledgeable about the trees they encountered. Because they gave only the common name, the exact scientific name was sometimes difficult to ascertain.

In fact, 2 kinds of trees named in the records we examined ("maple locust" and "locust hickory") could not be definitely assigned scientific names. The trees named most often in survey records were white oak (*Quercus alba*) 26%, pines (*Pinus* spp.) other than white pine (*P. strobus*) 13%, chestnut oak (*Q. prinus*) 10%, and hickories (*Carya* spp.) 9%. American chestnut (*Castanea dentata*), which is thought to have been an abundant species in the region at that time, represented only 5% of the total number of trees tallied. It is interesting to note that pines were recorded as being relatively more abundant on ridges and sides of hills than any other kinds of trees. White oak achieved this status at the bottoms of hills and on banks.

Records from surveys carried out by George Washington in northern Virginia and adjacent areas of West Virginia during the period 1748-1750 (Spurr, 1951) were fairly similar in overall tree composition to those compiled for Allegheny County (Figure 1). In both regions, these early forests were dominated by oaks, pines, and hickories. Oaks were slightly less abundant in Allegheny County than in northern Virginia, and there was a greater variety of other species present in the former region. The composition of forests in Allegheny County today appears to be rather similar, with dominance by oaks, particularly chestnut oak (*Quercus prinus*), pines, and hickories (Figure 2). At least some of the differences in relative dominance for the various tree species are probably attributable to differences in sampling methods. Data for present day forests in Allegheny County are based on studies by the second author and were obtained from 40 plots (each plot = 0.1 ha), located at 3.2 square kilometer intervals, mostly in the eastern half of the county. This grid was developed to assure that all habitat types within the county would be sampled. In contrast, early survey records tended to be limited mainly to bottomlands (where white oak typically is more abundant even today) in the central portion of the county.

The first general accounts of the forest vegetation of western Virginia date from the latter part of the last century. Among these are those of Hough (1878), who indicated that

"The Blue Ridge is mostly covered with forests of white, black, red, and rock oak, hickory, chestnut, locust, birch, some excellent yellow pine, and other trees. This section has furnished great quantities of charcoal for the manufacture of iron from the ores on its western margin, and it will long remain a source of supply as the forests renew themselves rapidly."

and also that

"Appalachia is both rich and poor in forestal wealth. On the Sandstone Mountain ranges, and in the slate and shale valleys, the trees are small, but the growth is dense, of oaks, and other hard woods, pines, &c., good for charcoal, with larger trees in the hollows and more fertile spots. On the limestone ridges and adjacent valleys, as also in the calcareous and some shale valleys, oaks, walnuts, white and yellow tulip-poplars, birches, beeches, locusts, cherries, sycamores, and other timber trees are found to grow to a large size, often several feet in diameter, and to a great height."

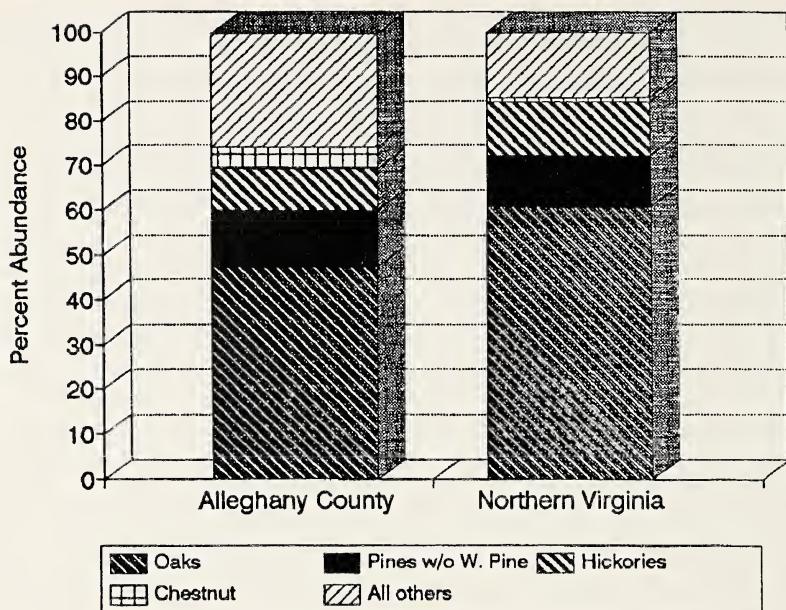


FIGURE 1. Comparison of early forest composition in Alleghany County, Virginia, and northern Virginia (and a portion of what is now West Virginia). Both are based on early survey records, with those for the northern Virginia area conducted by George Washington in the late 1700s (Spurr, 1951). Note overall similarity in composition. Oaks were slightly less abundant in surveys in Alleghany County, but there was a greater variety of other species.

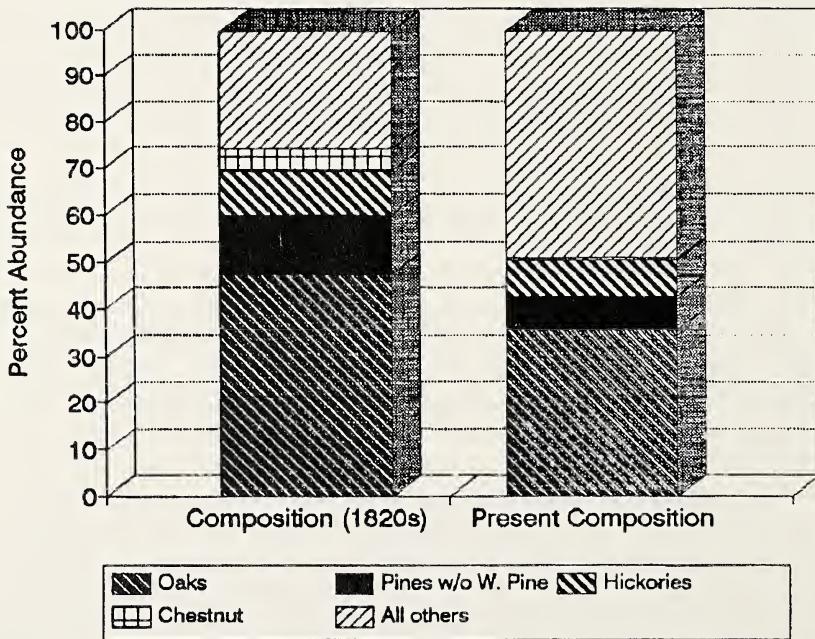


FIGURE 2. Comparison of early (survey records) and present (plot studies) forest composition in Alleghany County, Virginia. Composition is generally similar, although American chestnut has all but disappeared today. Present studies included more "other" species, presumably because more habitats were included than was the case for early surveys.

Only portions of this region have been reached by railroads, and extensive forests of excellent timber remain without means of reaching markets."

As a general observation, the trees named by Hough are the same as those recorded as important in recent studies of the upland forests of these same regions (e.g., Adams and Stephenson, 1983; Stephenson et al., 1991).

### CLEARING OF LAND FOR AGRICULTURE

When the first settlers arrived in eastern North America, they encountered what seemed to be an almost continuous forest. However, these pre-colonial forests were by no means completely undisturbed. Even in the more mountainous western portion of what is now Virginia, where Indian populations were probably never very high, some clearing of land for the cultivation of such crops as corn and beans had already taken place (Robison, 1960; Hudson, 1982). Most such cleared tracts of land were located in the fairly level mountain valleys, particularly along larger streams (Robison, 1960). For the most part, the earliest settlements in the region also tended to be located on the same types of sites. When these lands were settled, trees were girdled, chopped and burned as the forests were cleared to make way for homes and fields (Tice, 1987). As land in the stream valleys became increasingly scarce, settlers moved onto the lower slopes of the mountains, some of which had already been used for grazing livestock. However, relatively little use was ever made of steeper slopes and ridgetops, which were simply not suitable for agriculture. Based on figures provided by Hough (1878), the period during and immediately following the Civil War was marked by an unusually rapid reduction in forest acreage in western Virginia (Table 1). Nevertheless, even during the early part of the present century, when the amount of land being used for agriculture was at its peak, forests still occupied about half of the total land area in western Virginia (Table 2). Since that time, as more and more small farms have been abandoned, forest acreage has actually increased.

### FIRE AS AN ECOLOGICAL FACTOR

Fire represents an environmental factor of considerable importance in some types of forest ecosystems (Williams, 1991) and has undoubtedly played a major role in the evolutionary development of some tree species, including Table Mountain pine (*Pinus pungens*) (Zoebel, 1969). Before the advent of aboriginal man into eastern North America, most fires were caused by lightning. Ecological and meteorological evidence suggests that such fires were comparatively rare and affected a relatively small percentage of the total forest acreage (Van Lear and Waldrop, 1989). However, the frequency and ecological impact of fire increased dramatically upon the arrival of Indians in the region about 10,000 years ago (Keel, 1976; Van Lear and Waldrop, 1989). Apparently, wherever there were Indians, there was fire (Stewart, 1963). Indians purposefully used fire for a number of different reasons, including such things as driving game from cover, clearing the forest for agriculture, and removing undergrowth to make the gathering of acorns and chestnuts easier (Tice, 1987). Settlers began moving into the mountains of western Virginia in some numbers in the mid-1700s. To these early settlers, forests were considered a hindrance and fire was often used to clear areas of trees and/or undergrowth. In some locations, annual burning to retard the growth of woody

TABLE 1. Woodlands in various regions of Virginia reported as included in farms in 1860 and 1870. Figures given are numbers of acres and are from Hough (1878).

Region	1860	1870
Blue Ridge	413,944	349,381
The Valley	1,810,512	1,457,146
Appalachia	1,708,987	1,072,395

TABLE 2. Total land area by type of use in 1940. Figures given are from Lotti and Evans (1943).

Type of use	Area in acres	Percent of total land area
Forest		
Commercial	4,664,900	51.2
Reserved public	107,000	1.2
Non-commercial	184,400	2.0
Total forest	4,956,300	54.4
Non-forest		
Old cropland	1,622,700	17.8
New cropland	26,300	0.3
Pasture	2,209,100	24.2
Abandoned cropland	77,600	0.9
Other non-forest	214,000	2.4
Total non-forest	4,149,700	45.6
All uses	9,106,000	100.0

undergrowth in areas used for grazing livestock was a standard practice until well into the present century (Robison, 1960). Some evidence as to the extent and impact of fires in the forests of western Virginia in the late 1880s is provided by Hough (1882), who described the conditions that existed for a number of areas. For Allegheny County, Hough reported that

"Fires occurred in the mountains of this county in April and May, chiefly in a young growth of timber. Perhaps a tenth part of the wood-lands in this county are burned over annually.--(A. A. McAllister, Covington, Va.)"

and for Craig County, he noted that

"Fires occurred in February, March, and April, burning over a large area of mountain land and killing a considerable amount of timber.--(Z. T. Kale, Newcastle, Va.)."

As already indicated, fire was a relatively more important factor in certain types of forest communities than in others. For example, based on data for Shenandoah National Park (Table 3), some forest types were characterized by an exceedingly high frequency of fires, whereas fire was an uncommon occurrence in other types (Berg and Moore, 1941). During the present century, particularly since the 1920s, the fire suppression policies of the USDA Forest Service and other agencies have greatly reduced the use of fire in forests. Consequently, fire is less of a factor in forests than at any time in the recent past.

#### LOGGING OPERATIONS

The homes of early settlers were almost invariably constructed from logs or lumber produced from trees on or near the building site (Tice, 1987). In addition, considerable quantities of wood were used for fencing and as a source of fuel. At first, the actual impact of logging upon forests was relatively limited and quite localized. However, as the demand for wood increased, logging became more and more important. During the late 1800s, timber companies began buying large tracts of land in western Virginia, and by the beginning of the present century, even the most remote and inaccessible areas were being logged (Van Lear and Waldrop, 1989). In 1909 logging reached its peak in Virginia, with 2.1 billion board feet of lumber being produced, ranking the state sixth in the nation (Tice, 1987). Unfortunately, logging operations usually left behind a considerable amount of slash, which often burned. The resulting fires, some of which were deliberately set, were sometimes rather extensive and destructive.

The forests of western Virginia produced more than just logs for lumber. In a few areas (e.g., Allegheny County), where deposits of low-grade iron ore are found, appreciable amounts of wood were used to produce the charcoal used in iron furnaces during the period when these were in operation (which extended from the late 1700s through the 1800s). Moreover, the bark from such trees as chestnut oak was used in the tanning industry. It is interesting to note that the selective removal of chestnut oak seems not to have had a major impact upon the relative abundance of the species in at least those areas where it was most characteristic. Hough (1878) indicated that

"The lands upon which the chestnut oak grows in Virginia are mountain lands, too steep and rocky for any purpose of agriculture, other than vineyarding, orcharding, or perhaps with some of it, grazing, and are valuable only for bark, wood for smelting the iron ores abundant here, and of fine quality and high per cent. In this locality the furnace men utilize large quantities of the timber cut by the tanner. Bark forests, when cut down, do not give place to other kinds of timber, as is so frequently the case with other kinds of timber lands, but rapidly and thrifitly shoots up a new growth to the exclusion of the other timber, and, in time, renews the bark supply."

TABLE 3. Summary of total acreages and net burned acreages by each forest type for the period 1925-1940 in Shenandoah National Park. Figures given are from Berg and Moore (1941).

Forest Type	Total Acreage	Net Burned Acreage	Percentage Burned
Chestnut Oak	60,190	32,301	53.7
Red Oak	55,730	8,091	14.5
Open	29,450	402	1.4
Scarlet Oak	15,510	9,446	60.9
Pitch Pine	11,440	9,421	82.4
Cove Hardwoods	11,390	649	5.7
Bear Oak	6,710	6,158	91.8
Other	3070	187	6.1
Total	193,490	66,655	34.4

Chestnut oak continues to be an important species in the present-day forests of western Virginia and is often the single most abundant tree on southern exposures at moderate elevations (Adams and Stephenson, 1983; Stephenson et al., 1991).

#### INTRODUCED BIOTIC AGENTS

Introduced biotic agents have had a major impact upon the forests of western Virginia. Indeed, the single most important change in composition that seems to have occurred is the almost complete elimination (at least from the forest canopy) of the American chestnut by the chestnut blight.

Prior to the blight, which was introduced into North America at the beginning of this century, chestnut was one of the most abundant trees in the upland forests of the mid-Appalachians (Stephenson, 1986). Evidence as to the relative abundance of chestnut in forests of a portion of western Virginia just north of Allegheny County is provided by a description given by Ingalls (1949), who noted that

"Over huge areas chestnut was the dominant species. In the nineties anyone standing in front of the Homestead on a midsummer day and looking toward the warm Spring Mountains might have thought there had been a snowfall, so completely did the white chestnut blooms cover the slopes."

Quantitative descriptions of the pre-blight composition of chestnut-dominated forest communities are few in number, but in 1932 Braun (1950) surveyed one such community on the slopes of Salt Pond Mountain near Mountain Lake in Giles County. At that time, chestnut made up 85% of all stems in the forest canopy (Table 4). When this same community was resampled 50 years later, the species had disappeared completely from the canopy.

However, the potential for even greater change would seem to exist as a result of the spread of the gypsy moth (*Lymantria dispar*) into the forests of western Virginia. For many years this insect pest, which was introduced into North America from Europe in 1869, appeared to be contained in New England and eastern New

TABLE 4. Comparison of pre- and post-blight composition for a former chestnut-dominated community on an open, north-facing slope in the Mountain Lake area of southwestern Virginia. Values given are relative density.

Species	Date sampled	
	1932*	1982**
American Chestnut	84.6	0.0
Red Oak	11.1	57.0
White Oak	2.6	1.4
Red Maple	0.8	11.3
Cucumber Magnolia	0.8	0.5
Black Birch	0.0	5.4
Other species	0.0	24.4
Total	99.9	100.0

\*after Braun (1950)

\*\*after Stephenson (1986)

TABLE 5 Incidence of gypsy moth egg masses on stems  $\geq 10$  cm DBH in stands sampled on Massanutten Mountain and North Fork Mountain in 1990 (unpublished data supplied by D. Lawrence).

Study site	No. of stands	Incidence of gypsy moth egg masses (%)	
		Range	Mean
Massanutten	19	0-52	18.5
North Fork	22	0-42	5.0

York. However, during the latter part of the present century the gypsy moth has extended its range northward into Quebec, west to Michigan, and south through Maryland into Virginia. At the present time, the forests of western Virginia are on the leading edge of gypsy moth infestations. For example, based on data collected during the 1990 field season from forest stands on Massanutten Mountain (located in northern Virginia) and North Fork Mountain (located in eastern West Virginia), the incidence of gypsy moth egg masses is substantially higher for stands in northern Virginia than is the case for stands in regions farther west (Table 5).

Gypsy moth larvae are known to be capable of feeding upon the foliage of at least 500 different species of plants, but they show a decided preference for certain species, which often suffer extensive defoliation as a result. Forest trees that undergo repeated severe defoliations are subject to relatively higher levels of mortality than would otherwise be the case. Among the preferred tree species are

various oaks, including chestnut oak, black oak (*Quercus velutina*), red oak (*Q. rubra*), and white oak (Gansner and Herrick, 1985).

Because the major forest types in western Virginia contain a substantial oak component, they are particularly susceptible to gypsy moth defoliation.

In conclusion, despite past forest removal for agriculture, logging, and various other reasons, overall composition of today's forests appears to be fairly similar to that of presettlement forests. This perhaps illustrates the extraordinary resilience that is innate to these mid-Appalachian forest communities.

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#### LITERATURE CITED

- Adams, H. S., and S. L. Stephenson. 1983. A description of the vegetation on the south slopes of Peters Mountain, southwestern Virginia. *Bulletin of the Torrey Botanical Club* 110:18-22.
- Berg, L. Y., and R. B. Moore. 1941. The forest cover of Shenandoah National Park. Unpublished Report, Shenandoah National Park Library, Luray, Virginia. 66 pp.
- Bourdo, E. A., Jr. 1956. A review of the General Land Office survey and of its use in quantitative studies of former forests. *Ecology* 37:754-768.
- Braun, E. L. 1950. Deciduous forests of eastern North America. Hafner Publishing Company, Inc., New York. 596 pp.
- Chase, S. 1936. Rich land poor land. McGraw-Hill Book Company, New York. 361 pp.
- Gansner, D. A., and O. W. Herrick. 1985. Host preferences of gypsy moth on a new frontier of infestation. USDA Forest Service, Northeastern Forest Experiment Station, Research Note NE-330. 4 pp.
- Holland, C. G. 1980. Trees in deeds. Quarterly of the Archeological Society of Virginia (Spring 1980). pp. 117-129.
- Hough, F. B. 1878. Report upon forestry prepared under the direction of the Commissioner of Agriculture, in pursuance of an act of Congress approved August 15, 1876. Government Printing Office, Washington, DC. 650 pp.
- Hough, F. B. 1882. Report on forestry submitted to Congress by the Commissioner of Agriculture. Government printing Office, Washington, DC. 318 pp.
- Hudson, C. M. 1982. The southeastern Indians. University of Tennessee Press, Knoxville. 573 pp.
- Ingalls, F. 1949. The valley road. World Publishing Company, New York. 293 pp.
- Keel, B. C. 1976. Cherokee archaeology: a study of the Appalachian summit. University of Tennessee Press, Knoxville. 290 pp.
- Lipford, M. L., T. A. Mandeville, and H. S. Adams. 1985. Early forest composition in Allegheny County. *Virginia Journal of Science* 36:121.

- Lotti, T., and T. C. Evans. 1943. The forest situation in the mountain region of Virginia. USDA Forest Service, Appalachian Forest Experiment Station, Forest Survey Release No. 15. 70 pp.
- Radford, A. E., C. R. Bell, and H. E. Ahles. 1968. Manual of the vascular flora of the Carolinas. University of North Carolina Press, Chapel Hill. 1183 pp.
- Robison, w. C. 1960. Cultural plant geography of the middle Appalachians. Ph.D. Dissertation, Boston University, Boston, Massachusetts. 313 pp.
- Spurr, S. H. 1951. George Washington, surveyor and ecological observer. Ecology 32:545-549.
- Stephenson, S. L. 1986. Changes in a former chestnut-dominated forest after a half-century of succession. American Midland Naturalist 116:173-179.
- Stephenson, S. L., H. S. Adams, and M. L. Lipford. 1991. The present distribution of chestnut in the upland forests of Virginia. Bulletin of the Torrey Botanical Club 118:24-32.
- Stewart, L. O. 1935. Public land surveys. Collegiate Press, Inc., Ames, Iowa. 202 pp.
- Stewart, O. C. 1963. Barriers to understanding the influence of use of fire by aborigines on vegetation. Proceedings, Tall Timbers Fire Ecology Conference 2:117-126.
- Tice, D. A. 1987. A history of Albemarle's forests. Magazine of Albemarle County History 45:19-60.
- Van Lear, D. H., and T. A. Waldrop. 1989. History, uses, and effects of fire in the Appalachians. USDA Forest Service, Southeastern Forest Experiment Station, General Technical Report SE-54. 20 pp.
- Williams, C. E. 1991. Burning desire. Virginia Forests 47:28-31.
- Zoebel, D. B. 1969. Factors affecting the distribution of *Pinus pungens*, an Appalachian endemic. Ecological Monographs 39:303-333.



## Effects of Habitat Change From Ecological Succession and Human Impact on Tiger Beetles

C. Barry Knisley, Department of Biology

Randolph-Macon College, Ashland, Virginia 23005

James M. Hill, Maryland-National Capitol Park  
and Planning Commission, 8000 Meadowbrook Road,  
Chevy Chase, Maryland 20815

### ABSTRACT

This paper reports on 3 case histories of how changes in habitat have affected distribution and abundance of several species of tiger beetles in Virginia. Between 1980 and 1990, at a borrow pit site, the numbers of *Cicindela tranquebarica* decreased dramatically, *C. sexguttata* increased then decreased slightly, and *C. repanda* disappeared. These changes were associated with plant succession, specifically a rapid increase in density and size of loblolly pines throughout the site. The apparent extirpation of *Cicindela abdominalis* at a southeastern Virginia pine barrens habitat where it occurred in 1936 is believed to be the result of increased vegetation encroachment which eliminated open areas needed by this species. The distribution and abundance of *Cicindela dorsalis media* on barrier island beaches was correlated negatively with the amount of human impact. This species was abundant and widespread on Fisherman, Hog and Cobb Islands, but on Assateague was restricted to areas where vehicle and pedestrian use are low. The results of our study confirm the habitat-specific nature of tiger beetles and their need for open habitats with little human disturbance. Some species may quickly decline or disappear when their habitats change either naturally or from human activity.

Key Words: *Cicindela*, habitat, human impact, tiger beetles, succession

### INTRODUCTION

Tiger beetles are an interesting group of ground surface predators that attack small arthropods with short runs, using their large mandibles to capture and process prey. Ants are probably the most common prey but a variety of other organisms may be taken (Willis, 1967; Hori, 1982). Larvae are sedentary predators that live in burrows in the ground. They capture prey which passes within a few cm of their burrow opening. Typically, larval development through the 3 instars takes 1-3 years and occurs in the same burrow.

Preferred habitats of tiger beetles include water edges, sandy flats, dunes, woodland paths, open patches in grasslands and recently cleared areas. Most species are very habitat specific and the diversity of species in an area may be largely determined by the variety of suitable habitats (Willis, 1967; Knisley, 1984). A key habitat feature is bare ground, open to sunlight, which allows for behavioral thermoregulation (Dreisig, 1980) and the maintenance of the high body temperature necessary for prey capture (Dreisig, 1981).

Both natural processes and human activities may be responsible for creating and maintaining open areas and insuring the suitability of the habitat for tiger beetles. In his classic studies of ecological succession in the Lake Michigan dunes, Shelford (1908, 1911) demonstrated how the distribution of tiger beetle species changed with the progression of plant successional stages across increasingly older dunes. He also showed that the selection of an oviposition site by the adult female was the factor determining larval (and often subsequently adult) habitat. Elimination and disturbance of habitat were primary causes of the decline and possible extirpation of several tiger beetle species on the southern California coast (Nagano, 1980). Human impact on habitat, particularly off road vehicle (ORV) activity, was reported to be the factor responsible for the decline of *Cicindela oregonia* along an Arizona stream edge (Schultz, 1988) and *C. dorsalis* on coastal beaches in the Northeast (Knisley et al., 1987).

Among Virginia's tiger beetles (2 species of *Megacephala* and ca 18 species of *Cicindela*) are 6 rare or seldom collected species (Knisley, 1991). Of these, *Cicindela abdominalis*, *C. formosa*, and *C. limbalis* have not been collected recently and may have been extirpated because of loss of habitat. Other very common species like *Cicindela repanda*, *C. punctulata*, and *C. sexguttata* probably occur in every county and may benefit from activities of man which create edges and cleared, open areas. The objective of this paper is to present 3 case histories of the effects of habitat changes on some of these species. The case histories include: the change in abundance of 3 common species during natural succession of a borrow pit, the probable extirpation of a rare, localized species, *C. abdominalis* at a known site because of fire suppression and subsequent vegetation encroachment, and a study of the effects of human impact on *C. dorsalis media* on several barrier islands.

#### METHODS

The borrow pit studied was the Mechumps borrow pit located 2 km east of Ashland, Hanover County, Virginia. It was roughly oval-shaped, 260 m x 110 m. In the mid-1970's a 5-8 m layer of soil was removed from the surface, creating a very moist to waterlogged soil over most of the site. A small drainage ditch, which held water for several weeks after rains, and a shallow pond were also present (Fig. 1a). On the first visit to the site in spring 1980, tiger beetle abundance and vegetation were sampled. Vegetation samples included measurement of heights and nearest neighbor distances of woody plants along 5 50 m transects crossing the site. Vegetation was resampled in spring 1990.

Adult tiger beetles were sampled 1 to 2 times during peak abundance (April to early May) each year from 1980 to 1990 by walking through the open areas of the site and counting all beetles observed. The highest number counted in a year was used as that year's population size estimate. This census technique is a commonly used and effective method for determining tiger beetle abundance (Knisley, 1984, Hori, 1982). Larvae of *C. repanda* and *C. sexguttata* were sampled in May and June of 1980 and 1981 by walking the site and searching for burrow openings on the ground surface. All burrows found in 1980 were marked with numbered tags and checked at several week intervals through October and again the following spring to determine survival and progress of development (Knisley, 1987).

The Blackwater Ecologic Preserve (formerly known as Zuni Pine Barrens) in Isle of Wight County, Virginia, was surveyed for adult tiger beetles in July, 1988 and 1989. Trails, open patches and other areas of potential tiger beetle habitat were checked for adult beetles and the existence of suitable *C. abdominalis* habitat. Our description of the present vegetation at the site was based on our observations and information in Frost and Musselman (1987). Descriptions of the vegetation as it was in the 1930's is given in Fernald (1937, 1939) and Frost and Musselman (1987).

The study of human impact on *C. dorsalis media* involved a comparison of abundance of this species on several relatively undisturbed Virginia barrier islands and on Assateague Island where there are varying levels of beach use and human impact. Assateague Island includes a 42 km long shoreline portion of National Seashore and State Park in Maryland and a 16 km portion of Chincoteague National Wildlife Refuge in Virginia. The amount of human impact on the islands was determined by our observations of vehicle and pedestrian use during visits in 1985 and 1990 and from information provided by park personnel.

Censuses of adult *C. d. media* were done at times of highest beetle abundance (late June through early August) at least once between 1986 and 1990 by counting all beetles present along the water edge. Counts were made along the whole Assateague shoreline and along most of the shoreline (3-6 km lengths) at Hog, Cobb, and Fisherman Islands where beetles were present. These censuses thus give a rough estimate of total abundance on the islands. Larvae were sampled on Assateague in late August and October of 1990 and on Hog in September 1990, by counting all open larval burrows in 2 m wide transects across the beach from mid tide to back beach. At both islands we sampled 2 or more transects in areas where adult beetles had been most abundant.

Information of past and current distribution of *Cicindela dorsalis dorsalis* and *C. d. media* was obtained from our own collection records, from specimen label records of collections in major museums and private collections, from field notes provided by collectors, and from published records.

#### RESULTS AND DISCUSSION

**Borrow Pit Succession.** The vegetation and tiger beetle communities at Mechumps borrow pit changed dramatically between 1980 and 1990 (Fig. 1). Woody vegetation, mostly scattered loblolly pines, was very sparse in 1980. Mean nearest neighbor distance of pines was 26.0 m and mean height was 0.6 m throughout the site, except for a dense patch of trees which was apparently left intact when the soil was removed from this site (Fig. 1a). In 1990 loblolly pine mean nearest neighbor distance decreased to 2.2 m and mean height increased to 6.2 m, and all open areas were eliminated. The pond became more shallow and choked with vegetation but still held water and supported breeding frogs in 1990. The drainage ditch filled in and held little or no water, even after rains (Fig. 1b). Soil moisture seemed to decrease significantly, but we made no measurements to document this.

The dominant tiger beetle in 1980 was the water edge species *C. repanda* with over 200 adults counted, mostly near the stream edge. Larvae were concentrated along the ditch edge and at the base of the cliffs in early summer of 1980. Adults and larvae of *C. tranquebarica* were common but widely scattered throughout the

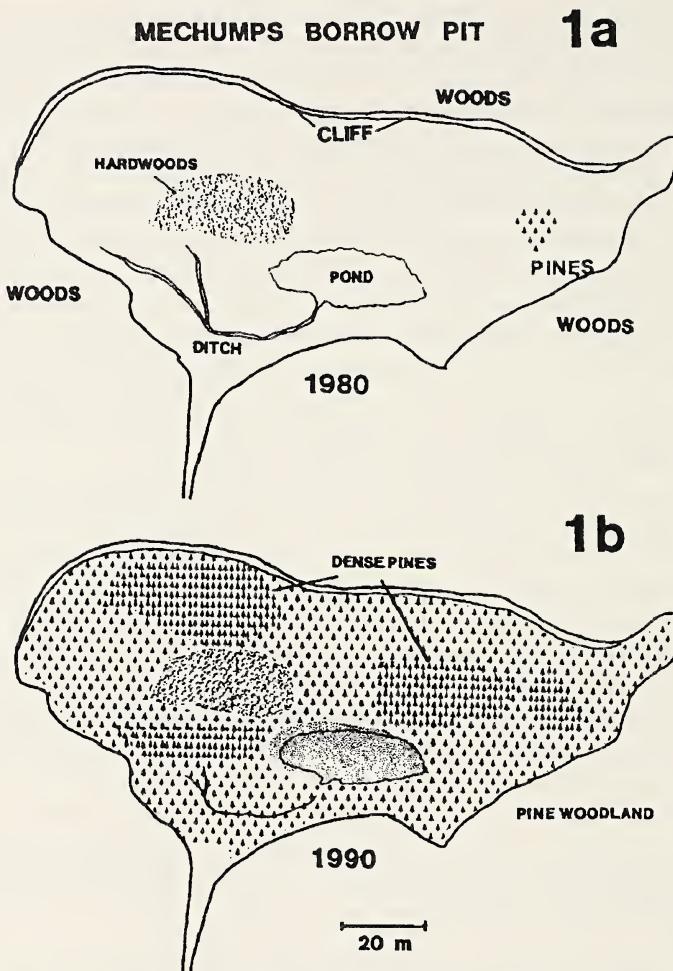


FIGURE 1. Map of Mechumps borrow pit in Hanover County, Virginia, showing the major features and vegetation at the site in 1980 (a) and in 1990 (b).

open flats. *Cicindela sexguttata*, a woodland species, was rare with only a few scattered individuals found. Numbers of these 3 species changed greatly after 1980 (Fig. 2). *Cicindela repanda* numbers declined very rapidly by 1982-1983 and then gradually until the species disappeared completely by 1986. The decline of *C. tranquebarica* was more gradual, with numbers dropping to < 15 by 1986 and continuing at that number until 1990. Numbers of *C. sexguttata* increased gradually to 40-50 by 1985 then declined slightly between 1986 to 1990.

We believe the changes in the composition of the tiger beetle community at this borrow pit are the result of changes in the habitat due to natural plant succession. Both adults and larvae of *C. repanda* and *C. tranquebarica* were probably affected by the decrease in open areas which adults apparently need for foraging and oviposition. Larvae of *C. tranquebarica* preferred the open flats which were largely eliminated by rapid encroachment of vegetation. *Cicindela repanda* larvae were

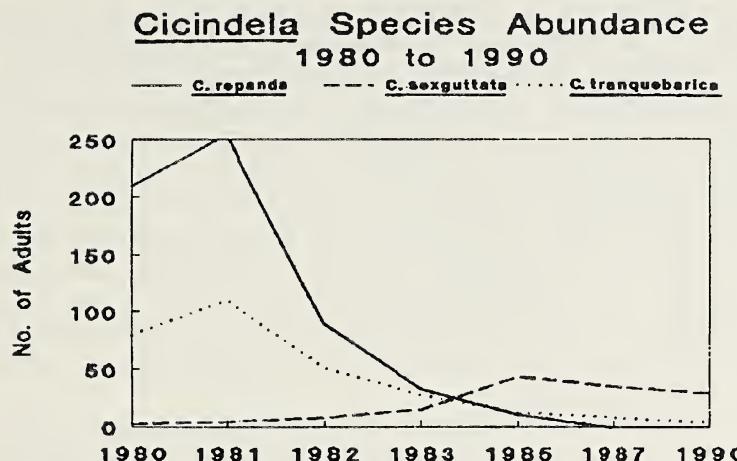


FIGURE 2. Yearly numbers of adults of 3 species of *Cicindela* at Mechumps borrow pit between 1980 and 1990. Numbers are the highest values of 1-2 yearly counts at the site during peak abundance and represent an estimate of the total population for each species.

present along the open areas near the steam bed, but these areas gradually dried out and became vegetated, making the habitat less favorable. *Cicindela sexguttata* may have benefited from the increased edge habitat created by growth of pines by 1984-86, then declined later as pines became more dense and eliminated some of the edge areas.

Studies of larvae at this site indicated some additional factors involved in the decline of these 2 species. About 85% of 150 first and second instars of *C. repanda* which were marked for observation in May 1981 did not survive beyond the second or early third instar. The cause of this high mortality may have been soil desiccation during a very dry 5-6 week period in June and early July. Soil desiccation can contribute to high rates of mortality in tiger beetle larvae (Knisley, 1987). A sample of *C. tranquebarica* larvae examined in summer 1981 indicated that nearly 75% of 120 were parasitized by the bee fly, *Anthrax analis*. Most or all of these larvae would have been killed by this parasite, thus reducing the number of new adults in 1982.

*Cicindela abdominalis*. This species is an inhabitant of deep sandy soils of open pine habitats (Boyd, 1978). It is known from pine barrens areas of New Jersey, North Carolina, South Carolina and Florida. There are no published Virginia records, but there are several specimens in the University of Richmond insect collection taken 5 km South of Zuni in 1936. This area is the Zuni pine barrens site, now known as the Blackwater Ecological Preserve. The beetles were taken by entomologist C. Williams on the same collecting trip that Fernald collected many rare pine barrens plants (Frost and Musselman, 1987).

We found no specimens of *C. abdominalis* during thorough surveys of this area in 1988 and 1989, suggesting it no longer exists at this site. If extirpated, the cause is probably the result of changes in its natural habitat brought about by the suppression of natural fires. Vegetation density has apparently increased since the 1930's, eliminating open areas preferred by this species. We found no large open

areas ( $>1000\text{m}^2$ ) when we surveyed this site, and vegetation cover was much greater than at sites in other states where we have collected this species.

In his initial visits to the site in 1936 Fernald (1937, 1939) indicated the presence of open areas, which were apparently maintained by periodic natural fires. The extirpation of some of the rare endemic herbs that Fernald found at the site was probably the result of the absence of fires which increased understory ericaceous shrubs and the loblolly-oak communities (Frost and Musselman, 1987). A plan of prescribed regular burning was recommended to prevent the loss of additional rare, disjunct savannah herbs which occur at the site. Burning has been implemented with the first burn in January 1986 (Frost and Musselman, 1987). The burning plan may make conditions again favorable for the reintroduction and establishment of *C. abdominalis*. This species may still occur in southeastern Virginia if other more open pine barrens sites exist.

The loss of this species is comparable to the rapid decrease and local extirpation of *Cicindela debilis* Bates in an Arizona grassland (Knisley, unpublished). Within 3 years the population went from 85 to 0 adults as grasses and herbs encroached and then completely covered several open patches where both adults and larvae had been found. Increased vegetation cover may reduce habitat quality for tiger beetles by eliminating oviposition sites and by decreasing adult foraging efficiency through interference with vision and thermoregulatory behavior.

*Cicindela dorsalis*. This case history includes a review of the effects of human impact on distribution and decline of *C. dorsalis* Say. Two of the 4 subspecies of *C. dorsalis* recognized by Boyd and Rust (1982) occur in Virginia. *Cicindela d. dorsalis* has a disjunct historic range from Cape Cod to central New Jersey and on beaches along both eastern and western shores of the Chesapeake Bay. This subspecies is Federally listed as Threatened (Jacobs, 1990) but is well established along the Chesapeake Bay, occurring at ca 40 sites. In the Northeast, however, it now occurs at only one site, on Martha's Vineyard Island. Its extirpation from Long Island, New Jersey and other northeastern sites is believed to be the result of disturbance and destruction of its coastal beach habitats through a variety of impacts, especially the increase in pedestrian foot traffic at many public and resort beaches, real estate and commercial development, and vehicular use on beaches (Knisley et al., 1987). Its survival at the Martha's Vineyard site is apparently because this site is so inaccessible and has been well protected for a long time (T. Simmons, pers. comm.).

But why does *C. d. dorsalis* survive at many sites within the Chesapeake Bay? The primary reason may be that none of these sites has received the level of human impact or disturbance typical of the northeastern sites. Most are privately owned with limited public access or for other reasons have little or no pedestrian or vehicle traffic. None of the sites is a heavy-use bathing or resort beach. There also exists within the Bay a large number of scattered suitable beach habitats of varying size which can support populations of this beetle over a wide area and allow for recolonization if some populations decline or are extirpated due to natural factors (Knisley et al., 1987).

*Cicindela d. media* is widespread and abundant on several of the Virginia barrier islands which we have surveyed, but like *C. d. dorsalis*, has declined in the northern part of its range. In Maryland it is listed as Endangered and occurs only on

Assateague Island. North of this, its only known occurrence is a recently discovered population on Little Egg Island, near Atlantic City (H. Boyd, pers. comm.). Unlike the other Atlantic and Cape May County, New Jersey sites where this species was present as late as the 1940's and 1950's, this site has received little human impact. Access is limited and the only apparent use is from a small number of fisherman and boaters, mostly on weekends. Some sites where *C. d. media* was once abundant, like Sea Isle City, Avalon, Ocean City, and Cape May, have become heavily used as public recreational or resort beaches. Other less accessible sites like Long Beach Island have received heavy vehicle use.

Our censuses of the 3 Virginia barrier islands (Cobb, Hog, Fisherman) indicated numbers of 1000 or more adults at each site (Fig. 3). These islands are a part of the Nature Conservancy's Virginia Coast Reserve and virtually undisturbed. On the 42 km section of Assateague in Maryland we counted 275 adults in 1986 and 375 in 1990. Nearly all of these were on the northernmost 5 km where human foot traffic is light and vehicle traffic is limited to a maximum of several trips per day by park personnel (Fig. 4). In 1985 and in 1990 we found no adults on the State Park and Sinepuxent development zone beaches. The only beetles present in the ORV zone were 13 individuals in 1990 within a 0.5 km section which had been roped off to protect a piping plover nesting area from vehicles. The State Park, Sinepuxent, and ORV areas all had clear evidence of beach disruption by vehicle activity. Glaser (1977) reported *C. d. media* from the Sinepuxent area in 1973 but found them absent in 1976 when he noted a great increase in ORV use which he suggested was the cause of their disappearance.

In the Virginia portion of Assateague we counted 40 beetles along the northernmost 2 km of beach in June 1986 and 15 beetles on the northern 6 km of wild beach in early July, 1990 (Fig. 4). An estimated 150 adult *C. d. media* were found on the bay side of the Toms Cove hook portion of the island in late June 1985. In none of the surveys were adults or larvae found on the public beach or ORV portions of Assateague in Virginia.

Censuses of larvae at Assateague indicated a similar pattern to that for adults except that larval numbers were generally low. In our 1990 surveys we found only 6 larvae in 20 transects from the Maryland portion of Assateague, and all were in the northern section of the island where adults were found. Twenty two were found in 5 transects in this northern section in 1986, but none in any transects to the south. On Hog Island in October 1990, we counted 71 larvae (48 second and 23 third instars) on one 2 m wide by 110 m long transect on the ocean side of the island and 4 larvae along a 26 m long transect on the bay side. These high numbers were due largely to the presence of larvae throughout the extremely wide, low beach.

The distribution of *C. d. media* on Assateague is clearly related to levels of beach habitat disturbance. Both ORV activity and heavy pedestrian foot traffic have apparently eliminated this species, probably by interfering with adult mating and oviposition and larval feeding, and by disrupting and compacting larval burrows. Also, ORV activity mixes up the soil and may interfere with the natural moisture gradient of larval burrows (Schultz 1988). The lesser beach slope and corresponding greater beach width on Hog and other barrier islands provides a greater amount of suitable habitat than at Assateague (Fig. 5). This is another factor contributing to the lower number of *C. d. media* on Assateague compared to the other barrier

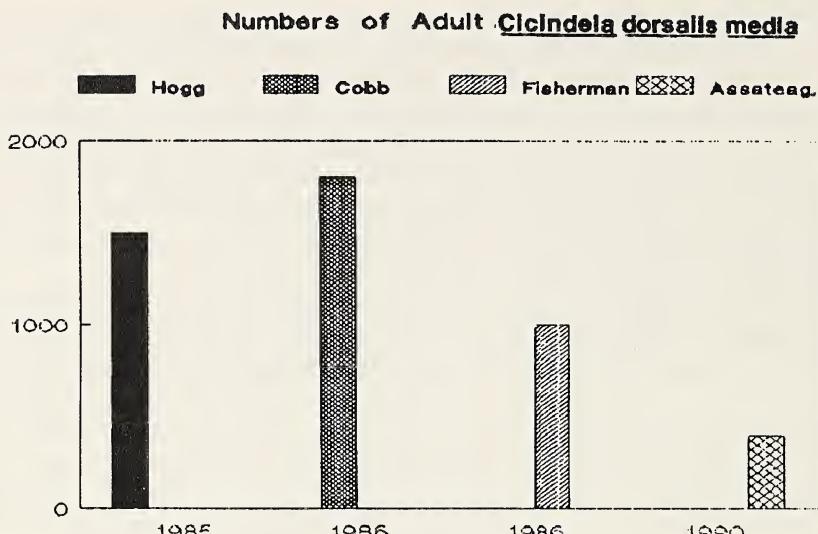


FIGURE 3. Numbers of *Cicindela dorsalis media* along the sandy beach at 4 barrier islands. Numbers are for the whole shoreline of Assateague and 3-6 km of beach where most adults were found at the other 3 islands.

islands. On the steeper, even narrower beaches within the Bay where *C. d. dorsalis* occurs (Fig. 5a), larvae occupy a much narrower band. The more gently sloping barrier beaches also have long tidal and washover zones which provide a much wider band of suitable larval habitat.

In summary, the results of this study demonstrate that tiger beetles are highly sensitive and can quickly respond to changes in their habitat, and may thus be useful as indicators of habitat type and quality. Natural successional changes and human activities are shown in this study to be two important factors affecting tiger beetle communities. While many species may quickly colonize new areas of habitat, as was apparently the case with *C. tranquebarica* and *C. repanda* at Mechumps borrow pit, they may also disappear quickly when conditions change. We have also shown how rare species like *C. dorsalis* may be limited by human disturbance to their habitat.

#### ACKNOWLEDGMENTS

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FIGURE 4. Map of Assateague Island showing features relevant to this study and location of *Cicindela dorsalis media*. Filled dots show specific locations of *C. d. media* (large dots indicate over 100 individuals each, smaller dots indicate fewer than 25 individuals each).

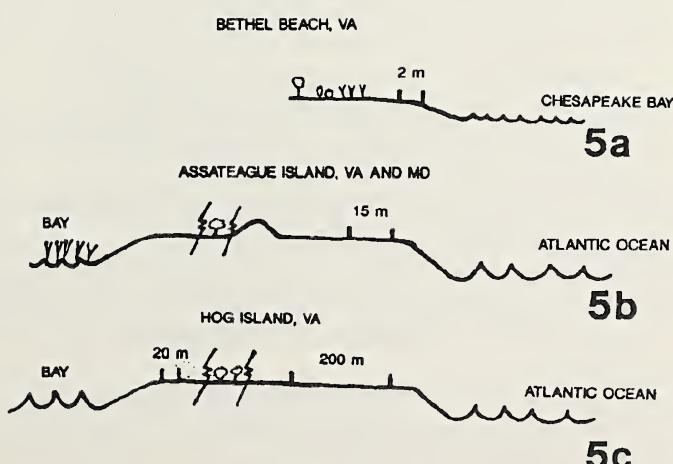


FIGURE 5. Diagrammatic profiles of 3 beaches showing the width of the larval habitat zone of *Cicindela dorsalis dorsalis* (a. Bethel Beach) and *C. d. media* (b. Assateague and c. Hog Island).

## LITERATURE CITED

- Boyd, H. P. 1978. The tiger beetles (Coleoptera: Cicindelidae) of New Jersey with special reference to their ecological relationships. *Transactions of the American Entomological Society* 104: 191-242.
- \_\_\_\_\_, and R. W. Rust. 1982. Intraspecific and geographic variation in *Cicindela dorsalis* Say (Coleoptera: Cicindelidae). *Coleopterists Bulletin* 36: 221-239.
- Dreisig, H. 1980. Daily activity, thermoregulation and water loss in the tiger beetle *Cicindela hybrida*. *Oecologia* 44: 376-389.
- \_\_\_\_\_. 1981. The rate of predation and its temperature dependence in a tiger beetle, *Cicindela hybrida*. *Oikos* 36: 196-202.
- Fernald, M. L. 1937. Local plants of the inner Coastal Plain of southeastern Virginia. *Rhodora* 39: 321-366.
- \_\_\_\_\_. 1939. Last survivors in the flora of Tidewater Virginia. *Rhodora* 41: 465-504.
- Frost, C. C. and L. J. Musselman. 1987. History and vegetation of the Blackwater Ecologic Preserve. *Castanea* 52: 16-46.
- Glaser, J. W. 1977. Letters from our readers. *Cicindela* 9: 12.
- Hori, M. 1982. The biology and population dynamics of the tiger beetle, *Cicindela japonica* (Thunberg). *Physiology and Ecology Japan*: 19: 77-212.
- Jacobs, J. 1990. Endangered and threatened wildlife and plants; determination of threatened status for puritan tiger beetle and the northeastern beach tiger beetle. *Federal Register* 55: 32088-32094.
- Knisley, C. B. 1984. Ecological distribution of tiger beetles (Coleoptera: Cicindelidae) in Colfax County, New Mexico. *Southwestern Naturalist* 29: 93-104.
- \_\_\_\_\_. 1987. Habitats, food resources, and natural enemies of a community of larval *Cicindela* in southeastern Arizona (Coleoptera: Cicindelidae). *Canadian Journal of Zoology* 65: 1191-1200.
- \_\_\_\_\_. 1991. Tiger beetles. pages 231-237 in K. Terwilliger ed. *Virginia's Endangered Species*. McDonald & Woodward, Blacksburg, Virginia.
- \_\_\_\_\_, J. I. Luebke, and D. R. Beatty. 1987. Natural history and population decline of the coastal tiger beetle, *Cicindela dorsalis dorsalis* Say (Coleoptera: Cicindelidae). *Virginia Journal of Science* 38: 293-303.
- Nagano, C. D. 1980. Population status of the tiger beetles of the genus *Cicindela* (Coleoptera: Cicindelidae) inhabiting the marine shoreline of southern California. *Atala* 8: 33-42.
- Schultz, T. D. 1988. Destructive effects of off-road vehicles on tiger beetle habitat in central Arizona. *Cicindela* 20: 25-29.
- Shelford, V. E. 1908. Life histories and larval habits of the tiger beetles (Cicindelidae). *Zoological Journal of the Linnaen Society* 30: 157-184.
- \_\_\_\_\_. 1911. Physiological animal geography. *Journal of Morphology* 22: 551-618.
- Willis, H. L. 1967. Bionomics and zoogeography of tiger beetles of saline habitats in the central United States (Coleoptera: Cicindelidae). *University of Kansas Science Bulletin* 47: 145-313.

## Effects of Changing land Use Patterns on Bobwhite Quail Habitat in Virginia

Michael L. Fies, Virginia Department of Game and Inland  
Fisheries, 1229 Cedars Court, Charlottesville, Virginia 22903

Irvin L. Kenyon, Jr., Virginia Department of Game and Inland  
Fisheries, Route 8, Box 1750, Ashland, Virginia 23005

Jack V. Gwynn, Virginia Department of Game and Inland  
Fisheries, 1229 Cedars Court, Charlottesville, Virginia 22903

### ABSTRACT

Bobwhite quail (*Colinus virginianus*) populations have been steadily declining in Virginia for at least 50 years. Wildlife biologists generally agree that changing land use patterns and more intensive agricultural methods are major factors contributing to this decline. A rapidly expanding human population now occupies many areas of former quail habitat. The total number and area of farms in Virginia have declined substantially since 1925. Many former open areas have reverted to forest that is no longer suitable for quail. Diverse mixtures of cereal grains have largely been replaced by monocultures of soybeans and improved grassland. Cattle production has increased, while the total area of pastureland has declined. The intensity of land use on farms has increased dramatically. Changing farm practices such as the removal of fencerows, fall plowing, double cropping, and the increased use of agricultural chemicals have been detrimental to quail. The fragmentation of remaining habitats has increased the vulnerability of quail to predation and other naturally occurring sources of mortality. Quail populations are likely to continue declining if current patterns of land use persist.

Keywords: bobwhite quail, *Colinus virginianus*, land use, agriculture, habitat

### INTRODUCTION

The decline in bobwhite quail populations throughout the Southeast has long been a subject of concern for biologists and sportsmen (Stoddard, 1931). According to Rosene (1969), quail numbers in the South increased until about 1890, remained at relatively high levels until 1940, then began a slow decline. Rosene blamed deteriorating habitat conditions due to increased pasture development and the decreased use of fire in forested areas for observed declines. From 1939 to 1948, Goodrum (1949) found "clean" farming and increased livestock production to be the two primary factors responsible for a nationwide decrease in quail numbers.

During colonial times, bobwhite habitat increased in Virginia as forests were cleared and put into agricultural production. Subsistence farming was a way of life for many Virginians and bobwhite quail flourished during this period. Cultivated fields were small, diverse, and supported an abundance of food-producing weeds (Stoddard, 1931). During the twentieth century, "pioneer agriculture" (Edwards,

1985) was gradually replaced by more intensive "clean farming" methods. The large fields and monocultures typically associated with modern agriculture were much less suitable as quail habitat (Roseberry and Klimstra, 1984). Urban expansion and development also destroyed many areas formerly occupied by quail.

Virginia quail populations have probably been decreasing for at least 50 years, yet there are few historical data to document observed declines. More recent data, however, provide convincing evidence of a downward trend. Droege and Sauer (1990) reported that the number of bobwhite quail heard on North American Breeding Bird Survey (BBS) routes conducted in Virginia between 1966 and 1988 declined 41.8%. Hunter surveys conducted by the Virginia Department of Game and Inland Fisheries show that the total number of quail bagged by Virginia sportsmen declined from almost 1.2 million birds in 1968 to fewer than 200,000 in 1989 (Gwynn, unpub. data), a decrease of 84 %. Also during this period, the number of quail hunters declined 79 %. Among those avid hunters who remained, the number of bobwhites harvested per day and per season declined 31 % and 25 % respectively.

Gehrken (1950) provides the only source of hunter success information prior to 1968. Compared to similar data from the same regions of the state that were collected in 1990 (Fies, unpub. data), the number of quail bagged per hunter hour declined 55 % since 1949. The number of coveys flushed per hunter hour decreased 62 % during this period. An annual survey of quail hunters conducted since 1979 (Fies, 1991) provides further evidence of a downward trend (Figure 1).

Despite the noticeable loss of quail habitat, rural landowners and sportsmen often do not understand why bobwhite quail populations have declined. "What happened to all the quail?" is one of the questions most frequently asked of Department of Game and Inland Fisheries biologists. The purpose of this paper is to document changes in agricultural land use that have occurred in Virginia since 1925 and to evaluate the effects of these changes on bobwhite quail habitat.

#### MATERIALS AND METHODS

To obtain agricultural land use data, statistics were compiled from Census of Agriculture reports published approximately every five years from 1925 to 1987 (U.S. Bureau of the Census, 1925, 1930, 1935, 1940, 1945, 1950, 1954, 1959, 1964, 1969, 1974, 1978, 1982, 1987). We chose the year 1925 as the starting point for our analyses because it represented the earliest year for which comparable census data were available for most variables measured. We obtained additional data on Virginia grain and hay crops from the Virginia Cooperative Crop Reporting Service (Virginia Department of Agriculture and Commerce, 1968).

General land use data and forest statistics for Virginia from 1940 to 1986 were compiled from U.S. Forest Service reports (Craig, 1949; Knight and McClure, 1967; Brown, 1986). We obtained information on human population growth from U.S. Bureau of Census Current Population Reports (U.S. Bureau of the Census, 1930, 1950, 1980). For 1990, we used population projections published by the Virginia Department of Planning and Budget (Lillywhite and Robinson, 1986). Our evaluation of the relationships between land use changes and bobwhite quail habitat is based upon descriptions of habitat quality by many authors (see review by Schroeder, 1985).

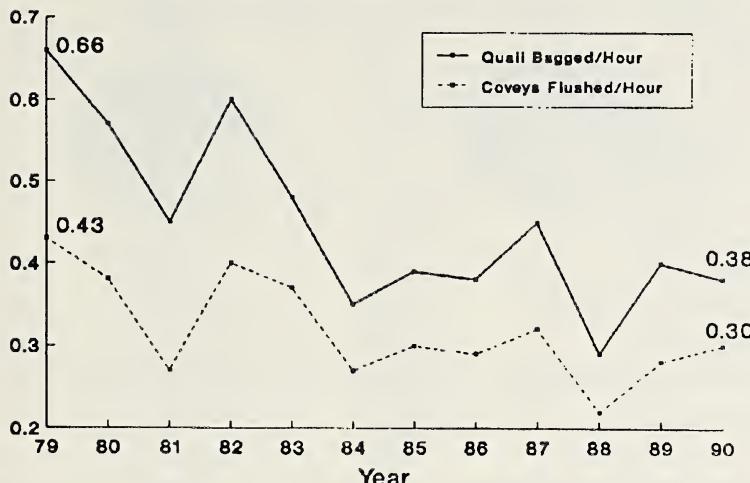


FIGURE 1. Number of quail bagged and coveys flushed per hunter hour during the 1979-80 through 1990-91 Virginia hunting seasons.

## RESULTS

In contrast to the lack of historic data regarding quail population levels, there is much information available on land use trends. In 1940, the U.S. Forest Service estimated that 25% of Virginia was comprised of cropland (Craig, 1949). Only 4% was classified as "other land" (residential, urban, roads, etc.). More recently, Brown (1986) estimated that the percentage of cropland in Virginia had declined to 14% while the percentage of "other land" increased to 10% (Figure 2). Forested area also increased from 58 to 63% during this period. These data suggest that increases in urban development and reforestation appear to have contributed almost equally to the loss of Virginia cropland.

Census of Agriculture data (U.S. Bureau of the Census, 1925-1987) provide further evidence that Virginia cropland is disappearing. Between 1925 and 1987, the total area of harvested cropland declined 39% in Virginia (Table 1). Not surprisingly, total farmland area also decreased, from almost 7 million ha in 1925 to approximately 3.5 million ha in 1987, a reduction of 50%. The total number of farms was reduced 76% from 185,697 to 44,798 farms and the average farm size almost doubled from 40.3 ha in 1925 to 78.4 ha in 1987 (Table 1).

Accompanying this downward trend in the total area of Virginia farmland has been a disproportionate loss in the number of small farms (less than 20 ha). In 1925, almost 50% of Virginia's farms were less than 20 ha in size and only 6% were 105 ha or larger (Figure 3). In 1987, 32% of all farms were less than 20 ha and 20% were 105 ha or larger. These comparisons reflect the change from small, diverse, "all purpose" farms to large, intensively managed monocultures.

The loss of farmland to urban development is a direct result of Virginia's rapidly expanding human population. According to the Bureau of Census, Virginia's population has increased 163% from 1920 to 1990. More importantly, the area of greatest human population growth has been in the Coastal Plain region, which

TABLE 1. Changes in selected agricultural statistics for Virginia, 1925 to 1987.

Item	1925	1987	% Change
Total Farmland (ha)	6,964,717	3,511,192	-49.6
Total Number of Farms	185,697	44,798	-75.9
Average Farm Size (ha)	40.3	78.4	+94.5
Harvested Cropland (ha)	1,606,025	974,069	-39.3
Corn Harvested (ha)	580,785	226,262	-61.0
Wheat Harvested (ha)	242,468	76,254	-68.6
Soybeans Harvested (ha)	38,710 <sup>1</sup>	186,125	+380.8
Hay Harvested (ha)	337,855	435,120	+28.8
Idle or Fallow Cropland (ha)	566,406	205,095	-63.8
Total Pastureland (ha)	2,139,977	1,356,109	-36.6
Number Cattle on Farms	806,524	1,510,920	+87.3
Number Cattle per 100 ha Pasture	37.7	111.4	+195.5

<sup>1</sup> Statistic for year 1930. No data available for 1925.

historically has had the greatest quail abundance (Kenyon and Gwynn, 1988). The human population in this region has increased 167% since 1920 (Figure 4).

Natural plant succession in abandoned fields has also been an important factor contributing to the decline in quail habitat. Although habitat conditions in abandoned fields are often favorable for quail during the first 4 years (Byrd, 1956), habitat quality quickly deteriorates as invading woody vegetation matures. Figure 5 shows that the area of forest in the seedling-sapling stage (which is often excellent quail habitat) increased 162% between 1956 and 1966 (Knight and McClure, 1967). This increase was due, in part, to the reversion of former cropland to forest. More importantly, an increased demand for pulpwood products during this period resulted in record levels of timber harvest and an increase in the area of early successional regrowth. Between 1966 and 1986, however, the area of seedling-sapling forest declined 37% (Brown, 1986). This decrease, and the corresponding increase in sawtimber area (Figure 5), were largely a result of the maturation of early successional seral stages.

Another important change in bobwhite quail habitat is related to the increased production of cattle and the higher grazing intensity of available pastureland. In Virginia, the total number of cattle on farms increased 87% between 1925 and 1987 (Table 1). The total area of available pastureland declined 37% during this period. As a result, grazing intensity on Virginia pastures (number of cattle per 100 ha of pastureland) increased almost 200% since 1925 (Table 1). The percentage of farm woodlands that are grazed has also risen substantially, from 19 % in 1925 to 26 % in 1987.

The types of crops harvested in Virginia have also changed significantly. Corn for grain was the principal crop harvested in 1925 (Figure 6). In 1987, hay was the most important crop harvested. Corn for grain dropped to the third most important crop, behind soybeans, for which harvest levels in 1925 were almost insignificant.

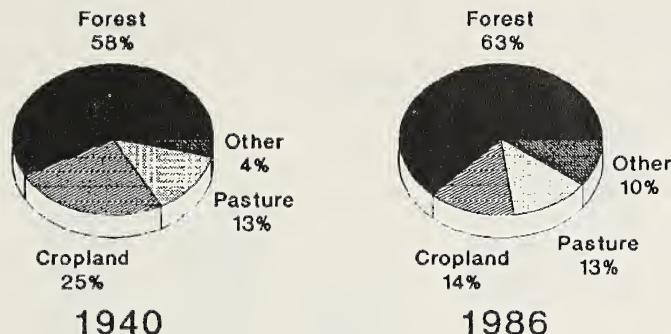


FIGURE 2. Percentage of all Virginia land by land use classification, 1940 versus 1986.

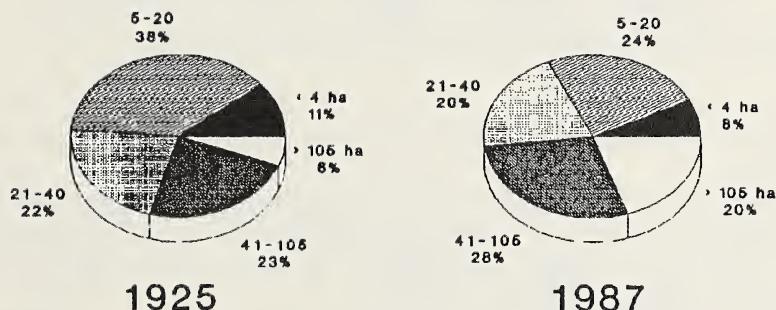


FIGURE 3. Percentage of Virginia farms by size class, 1925 versus 1987.

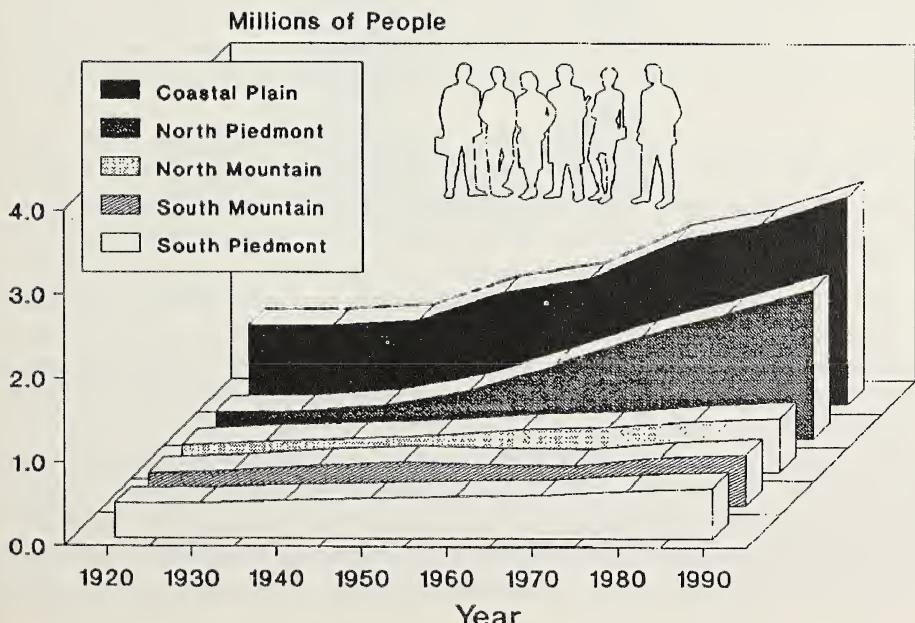


FIGURE 4. Human population in Virginia by geographic region, 1920 to 1990.

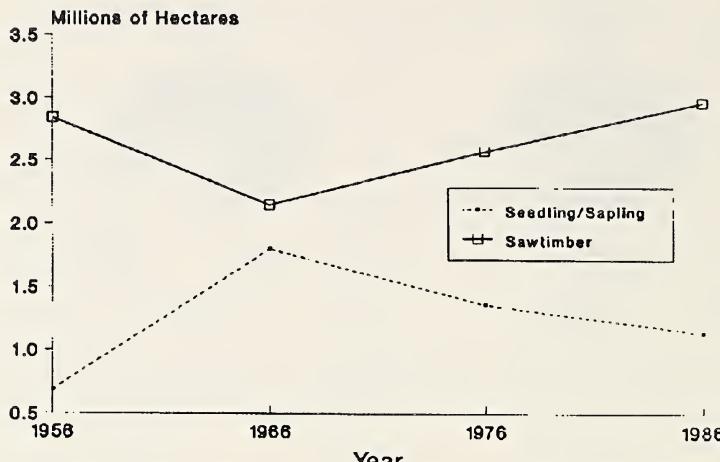


FIGURE 5. Hectares of Virginia forest land by timber size class, 1956 to 1986.

The total area of corn harvested for all purposes declined 61% from 1925 to 1987 (Table 1).

Along with this decline in the area of corn harvested has been a change in the way corn has been utilized. In 1925, 93% of Virginia's corn was harvested for seed or grain while only 7% was cut for silage. In 1987, corn harvested for silage comprised 39% of the total corn utilization.

Wheat is another important grain crop that has had a significant decline in land area harvested. From 1925 to 1987, the total area of wheat harvested in Virginia declined 69% (Table 1). Other grain crops, such as oats and rye, have followed similar trends but were less important crops during this period (fewer ha harvested). A notable exception to the general decline in grain crops has been the increase in the area of soybeans harvested, which has risen 381% since 1930 (Table 1).

The area on which hay is harvested in Virginia has also increased. From 1925 to 1987, the area of hay harvested rose 29% (Table 1). Accompanying this increase was a change in the types of crops that were used for hay. For example, lespedeza was a popular hay crop during the 1940's and 1950's and cowpea was often cropped for hay in the 1930's. In addition to providing forage for livestock, these legumes were also used as soil builders in crop rotation systems. Both of these crops were excellent quail foods and were valuable as nesting cover. Today, the use of these crops for hay is almost nonexistent as more chemical and natural fertilizers are used to enhance soil quality. A mixture of clover and timothy grass is presently the most common hay harvested in Virginia.

The area of idle or fallow fields, which are often prime quail habitat, is declining. Between 1925 and 1987, the number of ha left fallow or unharvested declined 64% (Table 1). As farm technology improved, more efficient utilization of available cropland became possible. Recently, the reduced participation in and availability of federal soil conservation and agricultural cropland set-aside programs has also

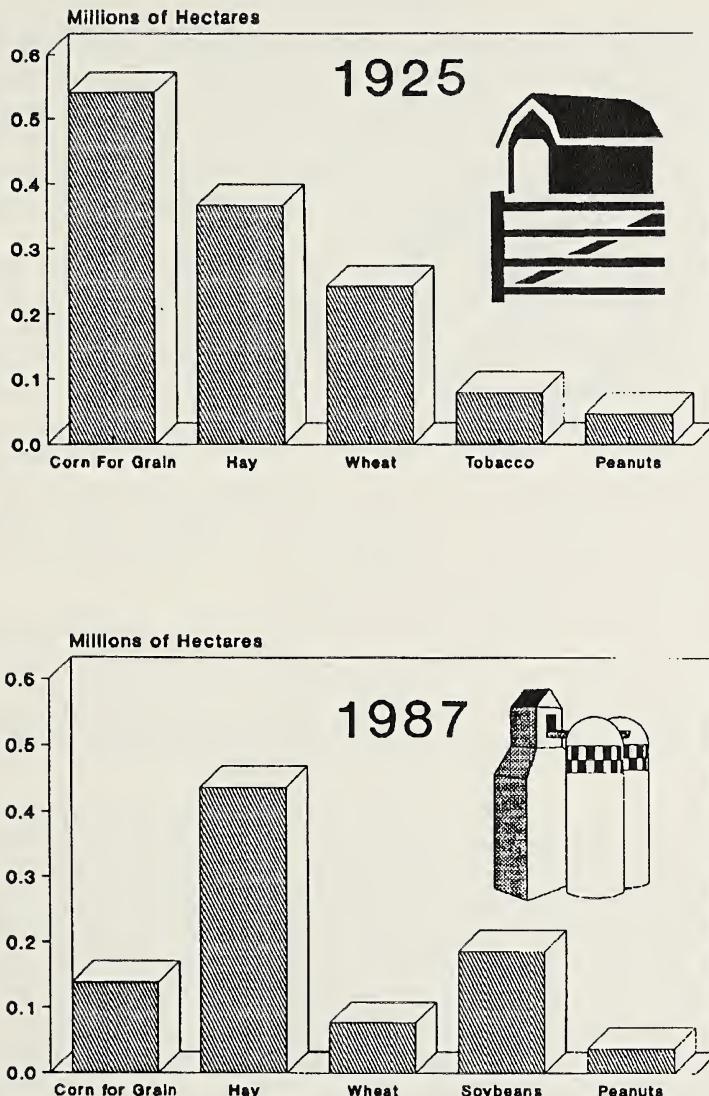


FIGURE 6. Comparison of major crops harvested (ha) in Virginia, 1925 vs. 1987.

resulted in fewer fields left unharvested. Also, adverse economic conditions have forced many farmers to boost production by cropping all available land area.

Farmers have also used agricultural pesticides to increase crop yields. Prior to the 1960's, the application of pesticides on Virginia farmland was relatively insignificant. Between 1969 and 1987, however, the use of pesticides to control insects, nematodes, disease, and weeds in Virginia crop fields increased 104% (Figure 7). Exposure to many of these chemicals is known to have adverse effects on avian species, including bobwhite quail (see review by Stinson, 1989).

### DISCUSSION

Considering the data presented, Virginia's agricultural landscape has been drastically altered since 1925. Because bobwhite quail are often associated with farmland habitats, their populations have been affected by these changes. The direct loss of habitat due to urban development and natural succession has contributed to the decline in quail numbers. The situation has been exacerbated by changes in farm technology and the agricultural economy that have resulted in more intensive use of remaining farmland habitats.

The increase in average farm size has been particularly significant. In general, larger farms have larger fields with fewer field borders. Since many "old-fashioned" field borders were weedy split-rail fences or brushy strips that provided excellent nesting and escape cover, the removal of this "edge" habitat adversely affected quail numbers. Farmers removed many fencerows to facilitate the use of large farm machinery and to maximize the use of available cropland. Other fencerows were removed because farmers believed that they harbored insect pests and were not consistent with the image of a "clean" farm. Regardless of the reason, removal of these fencerows resulted in decreased amounts of quality "edge" habitat, less diversity, reduced escape cover, and fewer travel lanes. Leopold (1931) eloquently described the need to protect hedgerow habitats:

"More game would be produced by in some way paying the farmer a bonus on hedges, than by spending the same money on foreign birds or Kansas rabbits. The fact that questions of this kind are not discussed, not investigated, nor even mentioned, is evidence that the game conservation movement has not yet come to grips with the real fundamentals of the problem which it intends to solve."

Changing land use has also had a great impact on bobwhite quail habitat by reducing or eliminating plant diversity and the interspersion of cover types, particularly those associated with the early stages of natural plant succession. Pimlott (1969) characterized habitat diversity as "the life blood of the majority of species," the ramifications of which "extend from the subsistence of an individual to the viability of a population and to the survival of species." For quail, increased plant diversity usually results in a greater range of food options (McRae et al., 1979) and is characteristic of prime nesting and escape cover (Klimstra and Roseberry, 1975). In contrast, the large-scale farming of monocultures reduces crop diversity and decreases the interspersion of habitat types. On a study area in Illinois, the conversion of a variety of crop fields to large soybean fields decreased the interspersion index for quail by 67 % (Vance, 1976). Baxter and Wolfe (1972) also demonstrated the importance of interspersion by documenting a significant positive correlation between the number of cover type changes with quail abundance along summer call-count routes.

The quantity and quality of "edge" habitat are also considered to be important measures of habitat quality. In fact, maximizing edge is considered to be an effective quail management tool (Conlin and Giles, 1972). The quality of edge habitat in Virginia, however, has declined as land use has changed. In 1925, the typical agricultural edge was comprised of a crudely farmed field adjacent to a weedy fence or brushy hedgerow. The cropped field provided a source of food and

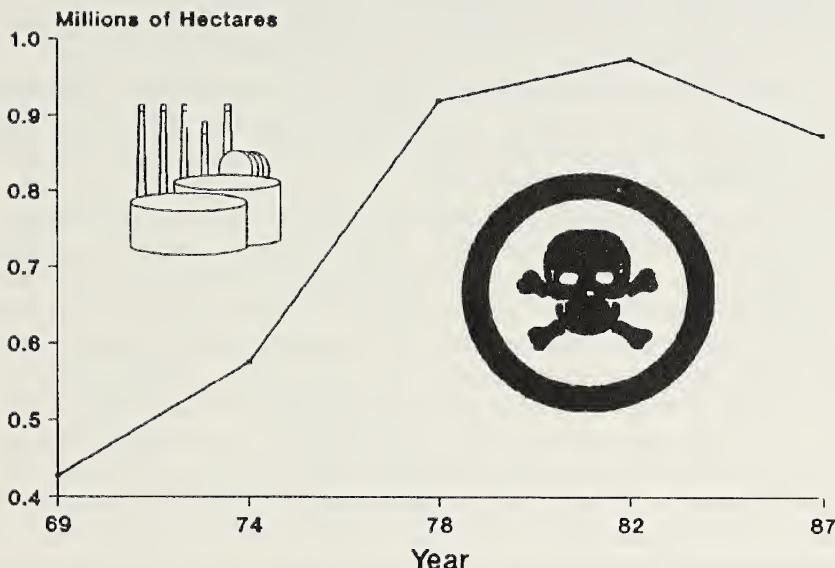


FIGURE 7. Hectares of Virginia cropland treated with insecticides, nematocides, fungicides, or herbicides, 1969 to 1987.

the weedy fencerow offered nesting and escape cover. In contrast, the modern edge is often a "clean" farmed field next to a mature woodland. Edges of heavily grazed pasture adjacent to grazed woodlands are also common. None of these habitat types are useful to quail.

Perhaps the greatest problem facing quail today is the lack of available nesting and brood range habitat. In earlier days, an abundance of rough pasture and fallow fields filled this important role. Today, most pastures are excessively grazed and are almost completely devoid of useful ground cover. Also, many intensively grazed pastures have been "improved" by replacing native grasses with sod-forming exotic species like fescue. Fescue conversion has been particularly detrimental to quail, and may be the single most important factor responsible for the observed decline in quail numbers. Matted growths of fescue are too thick for quail to utilize effectively and are unsuitable for nesting purposes (Roseberry and Klimstra, 1984:32). Even worse, fescue often takes over a field quickly by "choking out" other more useful quail plants. Fescue seed is also of little value as quail food (Michael and Beckwith, 1955).

The decline in grain crops harvested has affected quail by reducing the availability of winter foods. Quail often use waste grain from harvested corn fields as an important food source (Landers and Johnson, 1976). Wheat is also a preferred food (Michael and Beckwith, 1955). While the loss of these grain crops appears to have been partially offset by an increase in soybean area, only a small fraction of the soybeans remaining after harvest are used by quail. Waste grain in harvested soybean fields is usually plentiful, but quail will not frequent these areas because cover is limiting (Exum et al., 1982). Typically, soybeans are harvested

with combines that cut close to the ground, leaving almost no stubble for cover. Quail that feed in harvested soybean fields are often fully exposed to predators.

The increased percentage of corn that is harvested for silage has also contributed to the decline in winter food availability. Corn harvested for silage is cut earlier and there is less hardened crop residue left for winter food. Also, silage corn is cut close to the ground (to maximize use of the entire stalk), leaving no stubble available for fall and winter cover.

In general, the types of hay presently harvested in Virginia are less useful to quail than those harvested prior to 1950. In 1931, Herbert Stoddard considered common lespedeza to be "one of the most valuable of quail foods and pasture plants of the South." In Virginia, C. O. Handley (quoted in Kennedy, 1936) reported that the spread of lespedeza as a pasture crop was "becoming general enough to exert a tremendous influence toward the increase of quail." Unfortunately, the popularity of lespedeza hay declined rapidly during the 1940's and 1950's. Today, farmers rarely plant lespedeza as a hay crop and its area has dwindled to only a small fraction of that which it once occupied. Cowpea, also a preferred food of quail (Landers and Johnson, 1976), has followed a similar pattern of reduced popularity. The decline in the availability of these preferred quail foods has reduced the quality of habitat in many areas.

Perhaps more important than the loss of lespedeza and other hay crops beneficial to quail, have been the technological improvements developed for harvesting hay. In contrast to the former use of pitchforks and small balers, most hay is now baled using large package balers. The increased efficiency of these balers has contributed significantly to the increase in hay area harvested. Farmers are now harvesting many areas of suitable quail cover that would not have been hayed in the past (because of time or money constraints).

Increased farm technology and changing farm practices have had other detrimental impacts on quail habitat. Efficient farm machinery increased bobwhite nest destruction and reduced food availability through "clean" farming (Edminster, 1954). The development of the tractor and bulldozer also allowed for easy removal of fencerows. Improvements in mowing equipment (i.e. the bushhog) enabled farmers to clear brushy areas that were often attractive to quail. Fall plowing, double cropping, mowing for aesthetic reasons, and the reduced use of fire are other more recent farm practices that quail managers consider detrimental to quail.

The increased use of pesticides on Virginia farmlands may also be an important factor contributing to the decline in quail numbers. Aside from the direct mortality associated with exposure to toxic chemicals, sublethal doses can increase the susceptibility of quail to predation and decrease reproductive performance (Stromborg, 1982). Insecticides also reduce the number of insects available to developing quail chicks and can cause secondary poisoning when contaminated insects are eaten. The use of herbicides reduces the availability of native plant foods and decreases the amount of cover. Before the widespread use of herbicides, weedy corn fields provided excellent quail brood habitat. Today, "clean" corn fields are seldom used by quail broods.

Finally, the fragmentation of existing habitats has had a negative impact on Virginia quail populations. Large expanses of good quail habitat have been reduced to many small "islands" of suitable habitat. As a result of this fragmenta-

tion, quail are more susceptible to predation and other naturally occurring losses. Due to the relatively low mobility of bobwhites, recolonization of depleted habitats is often slow or fails to occur because of the reduced proximity of these areas to occupied range (Roseberry and Klimstra, 1984:194). Also, "island" quail populations have fewer surplus birds available to repopulate these areas. The detrimental effects of habitat fragmentation are more severe in areas of marginal habitat quality.

In summary, changing land use patterns and the intensity of land use have had profound effects on the availability and quality of quail habitat in Virginia. We attribute the current downward trend in quail population levels to these deteriorating habitat conditions. Although many of the factors discussed in this paper are at least partially responsible for the decline in quail numbers, we believe that loss of suitable nesting and brood range habitat has had the greatest negative impact.

Unfortunately, there is no reason to believe that quail populations will not continue to decline. To significantly increase quail numbers, it will be necessary to reestablish large areas of suitable quail range. Considering that the vast majority of quail habitat is on private land and that there is presently little economic incentive for landowners to make necessary habitat improvements, it seems unlikely that bobwhite populations will recover soon. The factors affecting quail abundance are well understood; what is lacking is the public's commitment to reverse the observed trends.

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#### LITERATURE CITED

- Baxter, W. L. and C. W. Wolfe. 1972. The interspersion index as a technique for evaluation of bobwhite quail habitat. *Proceedings National Bobwhite Quail Symposium* 1:158-165.
- Brown, M. J. 1986. Forest statistics for Virginia, 1986. *Resource Bulletin*. SE-87. U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station, Asheville, North Carolina. 67 pp.
- Byrd, M. A. 1956. Relation of ecological succession to farm game in Cumberland County in the Virginia Piedmont. *Journal of Wildlife Management* 20:188-195.
- Conlin, W. M. and R. H. Giles. 1972. Maximizing edge and coverts for quail and small game. *Proceedings National Bobwhite Quail Symposium* 1:301-305.
- Craig, R. B. 1949. Virginia forest resources and industries. *Miscellaneous Publication No. 681*. U.S. Department of Agriculture, Washington, D.C. 64 pp.
- Droege, S. and J. R. Sauer. 1990. Northern bobwhite, gray partridge, and ring-necked pheasant population trends (1966-1988) from the North American Breeding Bird Survey. In Church, K. E. et al. (eds.) *Perdix V: Gray Partridge and Ring-necked Pheasant Workshop*. 413 pp.
- Edminster, F. C. 1954. *American Game Birds of Field and Forest*. Charles Scribners Sons, New York. 490 pp.
- Edwards, W. R. 1985. Man, agriculture, and wildlife habitat -- a perspective. *Management Notes No. 5*. Illinois Natural History Survey, Champaign. 29 pp.

- Exum, J. H., R. W. Dimmick, and B. L. Deardon. 1982. Land use and bobwhite populations in an agriculture system in West Tennessee. Proceedings National Bobwhite Quail Symposium 2:6-12.
- Fies, M. L. 1991. 1990-91 quail hunter cooperators report. Unpublished report. Virginia Department of Game and Inland Fisheries, Charlottesville. 9 pp.
- Gehrken, G. A. 1950. Quail hunter records and their value. Proceedings Annual Conference Southeast Association Game and Fish Commissioners 4:166-171.
- Goodrum, P. 1949. Status of bobwhite quail in the United States. Transactions North American Wildlife Conference 14:359-367.
- Kennedy, I. N. 1936. Fluctuations in the population of bobwhite quail in the South. Transactions North American Wildlife and Resources Conference 1:481-486.
- Kenyon, I. L., Jr. and J. V. Gwynn. 1988. Quail status study. Pages 268-298. *In Virginia Wildlife Investigations Annual Report*. Department of Game and Inland Fisheries, Richmond.
- Klimstra, W. D. and J. L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildlife Monograph 41. 37 pp.
- Knight, H. A. and J. P. McClure. 1967. Virginia's timber, 1966. Resource Bulletin SE-8. U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station, Asheville, North Carolina. 47 pp.
- Landers, J. L. and A. S. Johnson. 1976. Bobwhite quail food habits in the southeastern United States with a seed key to important foods. Tall Timbers Research Station Miscellaneous Publication No. 4. 90 pp.
- Leopold, A. S. 1931. Report on a Game Survey of the North Central States. Sporting Arms and Ammunition Manufacturers Institute, Madison, Wisconsin. 299 pp.
- Lillywhite, D. P. and L. E. Robinson. 1986. Virginia population projections 2000. Department of Planning and Budget, Richmond. 96 pp.
- McRae, W. A., J. L. Landers, J. L. Buckner, and R. C. Simpson. 1979. Importance of habitat diversity in bobwhite management. Proceedings Annual Conference Southeast Association Game and Fish Commissioners 33:127-135.
- Michael, V. C., and S. L. Beckwith. 1955. Quail preference for seed of farm crops. Journal of Wildlife Management 19:281-296.
- Pimlott, D. H. 1969. The value of diversity. Transactions North American Wildlife and Resources Conference 34:265-280.
- Roseberry, J. L. and W. D. Klimstra. 1984. Population Ecology of the Bobwhite. Southern Illinois University Press, Carbondale. 259 pp.
- Rosene, W. 1969. The Bobwhite Quail, Its Life and Management. Rutgers University Press, New Brunswick, New Jersey. 418 pp.
- Schroeder, R. L. 1985. Habitat suitability index models: Northern bobwhite. U.S. Fish and Wildlife Service Biological Report 82(10.104). 32 pp.
- Stinson, E. R. 1989. Influences of agricultural chemicals on northern bobwhites in Virginia. Unpublished M.S. Thesis, Virginia Polytechnic Institute and State University, Blacksburg. 142 pp.
- Stoddard, H. L. 1931. The Bobwhite Quail: Its Habits, Preservation and Increase. Charles Scribners Sons, New York. 559 pp.
- Stromborg, K. L. 1982. Modern pesticides and bobwhite populations. Proceedings National Bobwhite Symposium 2:69-73.

- U.S. Bureau of the Census. 1920, 1930, 1950, and 1980. *Census of the Population: Virginia*. U.S. Government Printing Office, Washington, D.C.
- 1925, 1930, 1935, 1940, 1945, 1950, 1954, 1959, 1964, 1969, 1974, 1978, 1982, and 1987. *Census of Agriculture: Virginia*. U.S. Government Printing Office, Washington, D.C.
- Vance, D. R. 1976. Changes in land use and wildlife populations in southeastern Illinois. *Wildlife Society Bulletin* 4:11-15.
- Virginia Department of Agriculture and Commerce. 1968. *Virginia grain and hay crops*. Bulletin No. 32. 85 pp.



## Terrestrial Mammals of Virginia: Trends in Distribution and Diversity

Charles O. Handley, Jr., Division of Mammals,  
National Museum of Natural History  
Smithsonian Institution, Washington, DC 20560

### ABSTRACT

The present mammal fauna of Virginia dates from the late Pleistocene and early Holocene. Indians had little impact on the fauna, but European introduction of firearms led to terminal exploitation of bison and elk and to deliberate extirpation of large predators. Logging, clearing for agriculture, and urbanization had a negative impact on some forest species and brought gains for some open country species. The present era of conservation attempts to maintain diversity and to stabilize the fauna through protection, restoration, and management. Future challenges include: 1) Creating an informed and environmentally responsible citizenry by means of better education and public relations; 2) Maintaining diversity and ecological equilibrium by acquiring fundamental knowledge of natural history of all species as a primary management tool, managing for diversity of habitat and fauna, including both prey and predatory species, maintaining large roadless and relatively trailless wild areas connected by forest corridors, and establishing more and larger refuges to protect non-threatened as well as relict flora and fauna. Predictable future threats to mammals are from pressure of an expanding human population, global warming, and severe environmental perturbations such as acid rain and infestations of gypsy moths.

**Key Words:** mammals, Virginia, distribution, diversity, management, history, vagility

### INTRODUCTION

In historic times 75 species of indigenous terrestrial mammals, including bats, have occurred in Virginia. Most of these (45 species) have boreal (northern or cold) affinities (Tables 2-6). Fewer (30 species) have austral (southern or warm) relationships (Tables 8-10). The boreal segment of the fauna is rich in long-tailed shrews, moles, squirrels, voles, jumping mice, and carnivores. The austral segment includes the only marsupial, is rich in short-tailed shrews (including the state's most ubiquitous wild mammal, the northern short-tailed shrew), and has more species of bats and mice than the boreal segment.

This mixed fauna of northern and southern taxa had its roots in the late Pleistocene Wisconsin glacial age, 23,000--12,500 years B. P. (= before present) when continental glaciers were not far to the north, in Ohio, Pennsylvania, and New Jersey. At that time the tops of the higher mountains in Virginia probably had a treeless, alpine aspect; open, taiga-like parkland characterized lower mountain slopes; and on the piedmont and coastal plain, which then extended to near the edge of the continental shelf, was an open parkland with spruce, jack pine, fir,

birch, alder, and grass (Delcourt and Delcourt, 1986). Today's Chesapeake Bay was then the valley of the great Susquehanna River. In the late Pleistocene the Susquehanna with its major tributaries, the James and Potomac, was the largest river between the Mississippi and the St. Lawrence on the Atlantic Coast.

#### THE LATE PLEISTOCENE (23,000 to 12,000 years B. P.)

The mammalian fauna of the Wisconsin age in Virginia was a curious melange of old and new species. Remnants of the old fauna that thrived earlier in the Pleistocene still roamed the forests and plains of Virginia (Tables 1 and 7). There were a ground sloth, giant beaver, dire wolf, large cats, mastodon, mammoth, horses, tapir, peccaries, giant moose, and muskox. These giants became extinct at the end of the Pleistocene, while other contemporary megamammals such as black bear, mountain lion, bobcat, white-tailed deer, elk, moose, caribou, and bison survived into the Holocene. With very few exceptions the microfauna of Wisconsin time was the microfauna of the Holocene---today. The exceptions, a Pleistocene armadillo resembling *Dasypus bellus* and a round-tailed muskrat, *Neofiber leonardi*, died out along with the old Pleistocene megafauna when the climate abruptly warmed at the end of the Pleistocene (Eshelman and Grady, 1986).

The rich bone deposits beneath the ledges outside Clark's Cave in Bath County, Virginia, give us a window through which we can look back to late glacial time, 23,000 to 11,000 years B. P. What we see is astonishing by today's perspective. The edge of the continental glacier is not far to the north. Winters are moderate and summers are cool. Sheltered by limestone ledges above the cave mouth we look out over the valley of the Cowpasture River to the slopes of Warm Springs Mountain beyond. The mountain tops are bare, alpine. The slopes and valleys have a park-like boreal appearance, with scattered patches of spruce and pine, meadow and muskeg---taiga. Around the bend of the river on warmer west and south facing slopes there is denser temperate forest, perhaps with closed canopy (Guilday, et al., 1977).

This scene of diverse habitats can be reconstructed from the ecological preferences of the small mammals and birds represented in the Clark's Cave bone deposits. The Clark's Cave Fauna is a remarkably complete and varied assemblage (Tables 1 to 9). It cannot be said unequivocally that all of the species of the Clark's Cave Fauna cohabited the area simultaneously, but it is possible that they did (Guilday, et al., 1977).

Today Clark's Cave also has a diverse flora and fauna. There are northern plants such as giant woodfern, *Dryopteris goldiana*; southern resurrection fern, *Polypodium polypodioides*, and Carolina rhododendron, *Rhododendron catawbiense*; and relict white cedar, *Thuja occidentalis*, and yew, *Taxus canadensis*. At 1500 feet elevation the cave is too low for a boreal montane fauna, yet at or near the cave are 3 or 4 species of long-tailed shrews, southern red-backed vole, southern lemming vole, and woodland jumping mouse, all at the lower margin of their ranges. Elsewhere in Bath County or in adjacent Highland County all of the boreal relicts of Table 3 (except the extirpated porcupine) still can be found. On the other hand, austral species such as Virginia opossum, least shrew, Eastern cottontail, fox squirrel, and eastern harvest mouse, not part of the Clark's Cave

Fauna of 23,000 to 12,500 years B. P., are now in fields and forest at or near the cave.

Some species of the Clark's Cave Fauna and others that undoubtedly occurred there were especially adapted to cold and did not remain in Virginia as the climate warmed (Table 2). They moved northward and westward, following the retreating glaciers and boreal flora. Today these species live in a variety of boreal habitats--the 13-lined ground squirrel in the northern plains, from the Great Lakes states to central Alberta; yellow-cheeked vole and caribou in the tundra and taiga north of the boreal forest belt; the caribou also within the forest, along with Arctic shrew, least chipmunk, heather vole, northern lemming vole, marten, ermine, and moose.

Because the remains of Clark's Cave mammals were mostly deposited by owls, there is a bias for smaller species. Larger species in the deposits, such as snowshoe hare, woodchuck, porcupine, raccoon, black bear, marten, elk, and white-tailed deer must have been dragged to the cave mouth by larger carnivores. The fauna of large mammals nevertheless is under-represented. Most large species which must have occurred at Clark's Cave have been found in fossil deposits of similar age elsewhere in Virginia. These include gray wolf, red fox, fisher, river otter, mountain lion, bobcat, moose, caribou, and bison, as well as the extinct Pleistocene megamammals.

It is plausible that the high boreal faunal element (Table 2) was compressed southward during the Wisconsin glaciation, finally occupying a narrow area of familiar habitat and superimposing on marginal habitats already occupied by a resident boreal fauna (Tables 3 to 5). A general shift of habitats to lower latitudes during the Pleistocene would have removed at least some of the low boreal species of Table 6 and high austral species of Tables 8 and 9 from the vicinity of Clark's Cave. Medium austral species (Table 10) likely disappeared from Virginia altogether.

At the end of the Pleistocene, as glaciers retreated northward, high boreal habitats expanded, and there was a general northward shift of low boreal and high austral habitats. High boreal species (Table 2), compressed during the glacial interval, recoiled northward, eventually disappearing entirely from Virginia. Probably the mammals of Table 3 properly belong with those of Table 2 and represent the last stages of the recoil of high boreal species from southern latitudes into higher latitudes in the United States and Canada--north and west of Virginia.

The point to be made here, with reference to the Clark's Cave Fauna, is that major changes in habitat in a relatively short period of time (Delcourt and Delcourt, 1986) apparently resulted in minor changes in faunal composition. There were relatively small losses and gains among peripheral species of the boreal and austral segments of the fauna. This is somewhat surprising in view of the vagility of mammals. Even shrews and moles are vagile.

Emphatic testimony to vagility in the past is the present occurrence of so many species of mammals north of the boundary of Wisconsin glaciation in the northern United States and Canada (Handley, 1971). Locally, the peculiar fragmented range of the southern short-tailed shrew and the continuous distribution of the northern short-tailed shrew in eastern Virginia and North Carolina show the influence of parapatry and the effects of episodic movements of these species in the past. Even now we are witnesses to measurable movement of several species

of mammals in the eastern United States. The southeastern shrew is following closely the retreat of the masked shrew to higher elevations in the mountains of Virginia (Pagels and Handley, 1989). The Virginia opossum, nine-banded armadillo, and hispid cotton rat are moving northward. The prairie deer mouse (*Peromyscus maniculatus bairdii*) and the coyote have moved eastward from the prairies and now are proceeding southward on the Atlantic Coast.

The obvious potential for vagility in mammals emphasizes the flexibility of a majority of the Clark's Cave Fauna in choice of habitat. When the habitat at Clark's Cave changed from open boreal to closed temperate forest the diverse Clark's Cave Fauna could have shifted latitudinally with the vegetation, but few species moved (Tables 2 and 9). The implication is that in the future much of the mammalian fauna of Virginia should successfully absorb the impact of deliberate habitat modification by human beings and the impact of other environmental perturbations, whether natural or induced by human beings.

#### THE INDIANS (12,000 to 400 years B. P.)

Near the end of the Pleistocene, human beings came upon the scene for the first time. Judging by the variety of projectile points and skin scrapers that have been recovered in Virginia, the early people (Clovis Culture, 12,000 to 10,000 years B. P.) must have been primarily hunters (McCary, 1986). Some have postulated that they contributed to the disappearance of the old Pleistocene megafauna---ground sloth, mastodon, mammoth, tapir, etc., but somehow they spared the contemporary modern megamammals such as moose, elk, bison, etc. Oddly, no bones of old Pleistocene megamammals have been found in eastern North American Paleo-Indian sites (Gramly, 1982; McCary, 1986). Perhaps the sites are too young.

From about 12,000 years B. P. to about 400 years B. P. Indians harvested the megafauna but apparently had very little impact on it or on the microfauna. Rose (1986) reviewed reports of mammalian remains found at archeological sites in Virginia dated back to 4000 years B. P., and he listed 22 species squirrel-size or larger for the sites. White-tailed deer was most abundant. Other species utilized by Indians nearly statewide (no sites in the north, southeast, or on the Eastern Shore) were eastern cottontail, gray squirrel, woodchuck, beaver, muskrat, gray fox, black bear, raccoon, mountain lion, and elk. A few species were geographically limited: Virginia opossum was mostly in the piedmont and coastal plain, fox squirrel and red fox were only in the piedmont and coastal plain, eastern wood rat was only in the mountains and piedmont, and Eastern chipmunk was only in the mountains.

Rose (1986) speculated that the absence of remains of bison at all sites might be due to location of sites where bison did not occur or the probability that such a large animal would be butchered at the kill site rather than at the camp. I believe that at least in late prehistory in the Central Appalachians the Shawnee Indians treated as hunting reserves the white oak-blue grass savannahs on limestone karst, where elk and bison were most likely to occur. The Indians did not live in or near the savannahs, so they must have transported dried meat and hides dozens if not hundreds of kilometers back to their villages, as far away as Ohio.

## THE EUROPEANS (400 to 200 years B. P.)

The equilibrium that had existed for centuries between man and beast was shattered when the Europeans landed on the shores of Virginia. Whereas the impact of Indians on the mammals had been minimal, the impact of the European colonists was profound. In place of bows and arrows and spears, the colonists brought more lethal firearms. They also brought an exploitive philosophy, and in place of village, house, yard, and garden plot, they brought the concepts of fields, plantations, livestock, and cities.

The early colonists were impressed with the variety and abundance of game animals and large predators wherever they landed or settled. Late comers also reported the abundance of large mammals, not that they saw themselves, but that they heard of, on the frontiers to the west. Hunters became explorers as they ventured beyond the frontiers to find meat animals they could barter or sell back at the settlements. Predators were extirpated to protect livestock. Furbearers were trapped until there were too few for trapping to be worthwhile. The black rat (*Rattus rattus*) was inadvertently introduced; then later Norway rat (*Rattus norvegicus*) and house mouse (*Mus musculus*). They became feral, often the dominant mammals, in fields, marshes, ditch banks, sewers, thickets, and buildings (Handley, 1980).

The colonial era, 400 to 200 years B. P., ended with no more frontiers in Virginia. Settlement had reached every boundary. Two hundred years of unrestrained exploitation primarily affected the larger mammals. The bison was gone; elk, white-tailed deer, wolf, mountain lion, and beaver were reduced to small fractions of their precolonial numbers. Presumably the smaller mammals scarcely noticed the European presence, nor did the Europeans notice the smaller mammals enough to write anything significant about them.

## HABITAT DESTRUCTION (200 to 75 years B. P.)

The 19th century and the first quarter of the 20th century was the era of most severe habitat destruction in Virginia. Deforestation reached its maximum, with clearing for agriculture and clear-cutting for pulp and lumber; wetlands were drained for agriculture; streams were polluted with sewage, mine, and industrial wastes; and extirpation of fauna was commonplace.

The last of the original forest was clear-cut and the debris usually was burned. Forest fires were frequent and widespread. Growing on sterile ground, without benefit of long accumulated humus and soil nutrients, successional forests were inferior to the old growth they replaced. Trees we see today are comparatively low and scrawny, with no chance of ever attaining the status of forest giants, commonplace in the past.

Most tragic for mammals was the cutting and burning of the islands of spruce and fir on the higher mountains. This hastened the demise of the boreal relicts--the water shrew, snowshoe hare, northern flying squirrel, rock vole, and fisher. Most of these cling today to small fragments of only marginally suitable habitat, in numbers so small that their ultimate disappearance from Virginia is inevitable. When the European colonists replaced the parklike old growth forest of the coastal plain with a mosaic of agricultural fields, the fox squirrel survived in small numbers

in the most favorable habitat. However, in this century when the old fields were abandoned and grew up to scrub pine the fox squirrel disappeared.

Extirpation of mammals in Virginia peaked during this period: the last bison was killed in 1797; porcupine, about 1837; elk, 1855; mountain lion, 1882; fisher, 1890; the fox squirrel of the Eastern Shore, 1895; gray wolf, 1910; beaver, 1911; and the white-tailed deer and river otter were extirpated from most of western Virginia early in this century (Handley, 1980). Changing land use patterns led directly to extirpation of the fox squirrel, indirectly to extirpation of the others, making it easier in the shrinking forest to hunt or trap dwindling populations of mammals.

This era ended with an environmental disaster. The introduced chestnut blight reached northern Virginia about 1920 and had spread to the southwestern corner of the state by 1930. Quickly the oak-hickory-chestnut forest became an oak-hickory forest. The gray-white trunks of dead chestnuts became the dominant feature of mountain forests for the next quarter century. Ecological consequences were mixed. Disappearance of the chestnut was a serious sudden loss to mast foragers such as bear, deer, and turkey; but the standing dead trees provided optimal habitat for beetles and other burrowing arthropods, woodpeckers, and hole nesting birds and mammals; and later when the dead trees fell the prostrate trunks became habitat not only for invertebrates, but also for salamanders, snakes, shrews, chipmunk, mice, voles, and weasels.

#### CONSERVATION (75 years B. P. to present)

Actually conceived in the previous era, the conservation movement has developed in the 20th century. Virginia's mammals have prospered. The U. S. Forest Service, national and state forests and parks, forest management, soil conservation, wetland preservation, federal and state game management agencies, the non-game conservation program, the Natural Heritage movement, private conservation organizations, and the introduction of natural resources curricula to universities, all have had a profound effect on the mammalian fauna of Virginia. This has been an age of discovery, enlightenment, and recovery. The fauna has been inventoried and mapped and much has been learned about natural history and population dynamics. The Virginia Department of Game and Inland Fisheries now sees its role as steward of the whole fauna, not just of the game and fur species.

Attempts to restore lost species have had mixed success. Restoration of elk and snowshoe hare failed. Lack of suitable habitat in Virginia now compromises reestablishment of the fisher and limits the lowland fox squirrels. Reduction of pollution and trapping, and return of natural dispersal aided by transplants, probably will restore the river otter to western Virginia. Return of the mountain lion by informal transplants is likely to fail. Restoration of the white-tailed deer to western Virginia and the beaver to all of Virginia have been outstandingly successful.

Introduction of exotic taxa as a rule is undesirable. That certainly is true of the black and Norway rats and house mouse introduced unintentionally by the European colonists. The South American nutria (*Myocastor coypus*) has invaded salt marshes of Virginia from points of introduction in the southern United States. It may prove to be a valuable fur bearer or a pest. The black-tailed jackrabbit

(*Lepus californicus*) of the western United States, established on several islands of the Eastern Shore, in time probably will be considered a pest. The Japanese sika deer (*Cervus nippon*) flourishes on Assateague Island, where it is a tourist attraction and a game mammal. The Assateague pony (*Equus caballus*), touted as wild, actually is a managed domestic animal.

The 400 year saga of deforestation has ended. The acreage in forest in Virginia now is greater than it was 75 years ago and continues to grow as unprofitable farms are abandoned. Species which have benefited from deforestation---white-tailed deer, red fox, coyote, meadow vole, prairie deer mouse, harvest mouse, wood-chuck, chipmunk, and cottontail---probably are more widespread and abundant now than they have been since the Pleistocene. Reforestation is not likely to proceed to the point of seriously diminishing populations of these mammals. In fact, some reduction in their numbers is desirable. For example, the deer population has increased too much to be controlled by hunter harvest in some areas and consequent over-browsing is damaging habitat. Increasing acreage of forest and wilderness will benefit bear, mountain lion, bobcat, gray fox, and forest rodents and shrews.

#### ENVIRONMENTAL AWARENESS (The future)

#### THE PUBLIC

Education is the key to the future well-being of the flora and fauna. Increasingly sophisticated environmental education, public relations, advertising, and lobbying will create a majority constituency of voters actively concerned with environmental issues. They will not be satisfied with lip-service to conservation, promises of incremental future action on urgent issues, or reaction to crises based on economics. Atmospheric, freshwater, oceanic, and terrestrial pollution will be addressed properly and controlled. There will be greater resistance to the inclination of urban and highway planners and politicians to consider wilderness and wetlands as waste space, ideal for road corridors, land fills, and recreational parks.

#### NATURAL HISTORY

The greatest obstacle to effective management is ignorance of the basic natural history of most species. Only mammals of economic importance (mostly game, fur-bearing, or predatory species) are relatively well known. In the future, highest priority should be given to definitive studies of the natural history of those species that are threatened or endangered. Ultimately the biology of all species should be examined and habitat management decisions should be based on a firm knowledge of their natural history.

#### HABITAT MANAGEMENT

Much more attention must be given to *active* management of entire habitats. No longer should it be acceptable to just "let it grow." Had there been even a small amount of habitat management, the snowshoe hare might not be now on the verge of extirpation in Virginia. With prompt habitat management it may be still possible to create habitat suitable for fox squirrels on the Eastern Shore and in the southern coastal plain and piedmont of Virginia (Handley, 1991).

Breaking up even-age forest with small clear-cuts (Kirkland, 1990), prescribed burning, selective tree planting, and preservation of patches of surviving old growth

to create diversity and an artificial forest mosaic are forest management concepts that benefit mammals as well as many other animals. With a mosaic forest it is feasible to let forest fires burn, also a benefit for mammals.

Preservation of large roadless and relatively trailless blocks of forest, a challenging task in the face of burgeoning populations of human beings, is essential for perpetuation of large carnivores such as bear, bobcat, mountain lion, and fisher. Linking these blocks with forest corridors is a necessary component of the block scheme. In agricultural lands, farmers can create diversity simply by leaving fence rows weedy or shrubby and corners and damp ground wild. These practices benefit the farmer by providing habitat for small carnivores such as shrews, long-tailed and least weasels, and red foxes (Handley, 1991).

Virginia is fortunate in having most of its ocean fronting coastline and contiguous marshlands intact and protected. Wetlands of all types must be protected from filling, draining, flooding, polluting, and trampling. Small bogs and marshes in western Virginia are unprotected, unappreciated, and especially vulnerable. They provide habitat diversity that benefits many parts of the fauna, particularly birds, amphibians, and reptiles, as well as shrews, star-nosed mole, muskrat, lemming vole, harvest mouse, meadow jumping mouse, and mink.

Caves will come under increasing pressure for recreational spelunking. Management will be challenged to protect caves critical for bats, endangered or not, and yet to provide open or seasonal access for spelunkers to as many caves as possible.

#### GLOBAL WARMING

Natural ecological catastrophes such as hurricanes, tidal surges, tornados, ice storms, floods, droughts, and forest fires make short term drastic alterations of habitats on a local scale. Often they improve habitats for mammals by increasing plant diversity. Regional disasters on the scale of the chestnut blight, acid rain, and the invasion of gypsy moths, precipitated by human beings, have long lasting, perhaps permanent, impacts on the environment. New habitats may develop and parts of the flora and fauna may be lost. However, in scale these events are small in comparison with the global impact of the Pleistocene cooling or the global warming that may be in store for the world.

With substantial global warming we can expect large changes in the environment. Sea level will rise, inundating low-lying parts, perhaps large areas, of the coastal plain. There will be a latitudinal shift of floras. In Virginia, many species including spruce, fir, hemlock, clubmosses, and boreal ferns may disappear from the mountains; austral pines, gums, magnolias, pitcher plants, jasmine, and other southern plants may colonize the lowlands. Much of the mammal fauna will remain the same, but the high boreal species (Table 3) and some medium boreal species (Table 4) may be extirpated. Other medium boreal species (Table 4) could become mountaintop relicts, while others (Table 5) may become restricted to the mountains. The species of the other tables might move similarly, until eventually some or all of the low austral/tropical species (Table 11) would make their appearance in Virginia.

Lessons of the past, examined in this paper, assure us that if we protect and manage the flora and fauna intelligently we can maintain an optimum level of diversity. Climatic events beyond our control may force variation in composition of the flora and fauna but should not affect species richness.

TABLE 1. EXTINCT BOREAL SPECIES. Extinct by early Holocene; no survivors anywhere.

\* Occurred in Clark's Cave Fauna.

<i>Castoroides ohioensis</i>	giant beaver
* <i>Canis cf. C. dirus</i>	dire wolf
<i>Panthera</i> sp. or <i>Felis atrox?</i>	"large cat"
<i>Mammut americanum</i>	American mastodon
<i>Mammuthus primigenius</i>	woolly mammoth
<i>Equus complicatus</i>	horse
<i>Equus cf. E. fraterculus</i>	horse
? <i>Sangamona</i> sp.	deer
? <i>Cervalces</i> sp.	giant moose
<i>Bootherium bombifrons</i>	woodland muskox

TABLE 2. HIGH BOREAL SPECIES. Extirpated prehistorically from Virginia; still occurring north and/or west of Virginia. \* Occurred in Clark's Cave Fauna.

* <i>Sorex arcticus</i>	Arctic shrew
* <i>Tamias minimus</i>	least chipmunk
* <i>Spermophilus tridecemlineatus</i>	13-lined ground squirrel
* <i>Phenacomys intermedius</i>	heather vole
* <i>Microtus xanthognathus</i>	yellow-cheeked vole
* <i>Synaptomys borealis</i>	northern lemming vole
* <i>Martes americana</i>	marten
* <i>Mustela erminea</i>	ermine
cf. <i>Alces alces</i>	moose
<i>Rangifer tarandus</i>	caribou

TABLE 3. HIGH/MEDIUM BOREAL SPECIES. Relicts in mountains of Virginia; small isolated populations, all in danger of extirpation in Virginia. \* Occurred in Clark's Cave Fauna.

* <i>Sorex palustris</i>	water shrew
* <i>Plecotus townsendii</i>	western big-eared bat
* <i>Lepus americanus</i>	snowshoe hare
* <i>Glaucomys sabrinus</i>	northern flying squirrel
* <i>Microtus chrotorrhinus</i>	rock vole
* <i>Erethizon dorsatum</i>	porcupine, EXTIRPATED
<i>Martes pennanti</i>	fisher, EXTIRPATED, restoration attempted

TABLE 4. MEDIUM BOREAL SPECIES. Restricted in Virginia to mountains; populations continuously distributed. \* Occurred in Clark's Cave Fauna.

* <i>Sorex cinereus</i>	masked shrew (mountains and Eastern Shore)
* <i>Sorex dispar</i>	big-tailed shrew
* <i>Sorex fumeus</i>	smoky shrew
* <i>Parascalops breweri</i>	hairy-tailed mole
* <i>Sylvilagus transitionalis</i>	New England cottontail
* <i>Peromyscus maniculatus</i>	deer mouse
* <i>Clethrionomys gapperi</i>	southern red-backed vole
* <i>Synaptomys cooperi</i>	southern lemming vole
* <i>Napaeozapus insignis</i>	woodland jumping mouse
<i>Canis latrans</i>	coyote (recent immigrant)

TABLE 5. MEDIUM BOREAL SPECIES. Statewide in distribution, except absent from coast or Southeast. \* Occurred in Clark's Cave Fauna.

* <i>Sorex hoyi</i>	pygmy shrew
* <i>Myotis leibii</i>	little-footed myotis
* <i>Myotis septentrionalis</i>	northern myotis
* <i>Tamias striatus</i>	eastern chipmunk
* <i>Marmota monax</i>	woodchuck
* <i>Tamiasciurus hudsonicus</i>	red squirrel
* <i>Zapus hudsonius</i>	meadow jumping mouse
* <i>Mustela nivalis</i>	least weasel
* <i>Mephitis mephitis</i>	striped skunk
* <i>Cervus elephas</i>	elk, EXTRIPATED, restoration failed
<i>Bison bison</i>	bison, EXTRIPATED

TABLE 6. LOW BOREAL SPECIES. Statewide in distribution. \* Occurred in Clark's Cave Fauna.

* <i>Scalopus aquaticus</i>	eastern mole
* <i>Condylura cristata</i>	star-nosed mole
* <i>Myotis lucifugus</i>	little brown myotis
<i>Lasionycteris noctivagans</i>	silver-haired bat
* <i>Eptesicus fuscus</i>	big-brown bat
* <i>Sciurus carolinensis</i>	gray squirrel
<i>Castor canadensis</i>	beaver, EXTRIPATED, restored
* <i>Peromyscus leucopus</i>	white-footed mouse
* <i>Microtus pennsylvanicus</i>	meadow vole
* <i>Ondatra zibethicus</i>	muskrat
<i>Canis lupus</i>	gray wolf, EXTRIPATED
<i>Vulpes vulpes</i>	red fox
* <i>Ursus americanus</i>	black bear
* <i>Mustela vison</i>	mink
<i>Lutra canadensis</i>	river otter
<i>Felis concolor</i>	mountain lion, EXTRIPATED?
<i>Felis rufus</i>	bobcat

TABLE 7. EXTINCT AUSTRAL SPECIES. Extinct by early Holocene; no survivors anywhere. Not found in the Clark's Cave fauna.

<i>Megalonyx jeffersonii</i>	Jefferson's ground sloth
<i>Dasyus cf. D. bellus</i>	armadillo
<i>Neofiber leonardi</i>	round-tailed water rat
<i>Tapirus cf. T. veroensis</i>	Vero tapir
<i>Mylohyus nasutus</i>	long-nosed peccary
<i>Platygonus compressus</i>	flat-headed peccary

TABLE 8. HIGH AUSTRAL SPECIES. Restricted in Virginia to mountains; mostly relicts.

\* Occurred in Clark's Cave Fauna.

* <i>Myotis grisescens</i>	gray myotis
<i>Myotis sodalis</i>	social myotis (not distinguished from <i>M. lucifugus</i> in Clark's Cave material)
* <i>Pipistrellus subflavus</i>	eastern pipistrelle
* <i>Neotoma floridana</i>	eastern wood rat
<i>Spilogale putorius</i>	eastern spotted skunk

TABLE 9. HIGH AUSTRAL SPECIES. Statewide in distribution. \* Occurred in Clark's Cave Fauna.

<i>Didelphis virginiana</i>	Virginia opossum
<i>Sorex longirostris</i>	southeastern shrew (marginal in mountains, not on Eastern Shore)
* <i>Blarina brevicauda</i>	northern short-tailed shrew
<i>Cryptotis parvus,</i>	least shrew
* <i>Lasiurus borealis</i>	northern red bat
<i>Lasiurus cinereus</i>	hoary bat
<i>Sylvilagus fodiatus</i>	eastern cottontail
<i>Sciurus niger</i>	fox squirrel
* <i>Glaucomys volans</i>	southern flying squirrel
<i>Reithrodontomys humulis</i>	eastern harvest mouse (not on Eastern Shore)
* <i>Microtus pinetorum</i>	pine vole
<i>Urocyon cinereoargenteus</i>	gray fox
* <i>Procyon lotor</i>	raccoon
<i>Mustela frenata</i>	long-tailed weasel
* <i>Odocoileus virginianus</i>	white-tailed deer

TABLE 10. MEDIUM AUSTRAL SPECIES. Restricted in Virginia to the eastern, southeastern, or southern portions of the state. None of these species were found in the Clark's Cave Fauna.

<i>Blarina carolinensis</i>	southern short-tailed shrew
<i>Lasiurus intermedius</i>	greater yellow bat
<i>Lasiurus seminolus</i>	Seminole bat
<i>Nycticeius humeralis</i>	evening bat
<i>Plecotus rafinesquii</i>	eastern big-eared bat
<i>Sylvilagus palustris</i>	marsh rabbit
<i>Oryzomys palustris</i>	northern rice rat
<i>Peromyscus gossypinus</i>	cotton mouse
<i>Ochrotomys nuttalli</i>	golden mouse
<i>Sigmodon hispidus</i>	hispid cotton rat

TABLE 11. LOW AUSTRAL/TROPICAL SPECIES. Entire range south of Virginia. None of these species were found in the Clark's Cave Fauna.

<i>Myotis austroriparius</i>	southeastern myotis
<i>Tadarida brasiliensis</i>	Brazilian free-tailed bat
<i>Eumops glaucinus</i>	glaucous mastiff bat
<i>Dasyurus novemcinctus</i>	nine-banded armadillo
<i>Sylvilagus aquaticus</i>	swamp rabbit
<i>Geomys pinetis</i>	southeastern pocket gopher
<i>Peromyscus polionotus</i>	old field mouse
<i>Podomys floridanus</i>	Florida mouse
<i>Baiomys taylori</i>	dwarf mouse
<i>Neofiber alleni</i>	round-tailed muskrat
<i>Nasua narica</i>	coati
<i>Felis pardalis</i>	ocelot
<i>Tayassu tajacu</i>	collared peccary

#### LITERATURE CITED

- Delcourt, H. R., and P. A. Delcourt. 1986. Late Quaternary vegetational change in the Central Atlantic States. Pp. 23- 35 in J. N. McDonald and S. O. Bird, eds., The Quaternary of Virginia---a symposium volume. Virginia Division of Mineral Resources Publication 75.
- Eshelman, R., and F. Grady. 1986. Quaternary vertebrate localities of Virginia and their avian and mammalian fauna. Pp. 43-70 in J. N. McDonald and S. O. Bird, eds., The Quaternary of Virginia---a symposium volume. Virginia Division of Mineral Resources Publication 75.
- Gramly, R. M. 1982. The Vail site: A Paleo-Indian encampment in Maine. Buffalo Society of Natural Science 30:1-169.

- Guilday, J. E., P. W. Parmalee, and H. W. Hamilton. 1977. The Clark's Cave bone deposit and the late Pleistocene paleoecology of the Central Appalachian Mountains of Virginia. *Bulletin of the Carnegie Museum of Natural History* 2:1-87.
- Handley, C. O., Jr. 1971. Appalachian mammalian geography---Recent Epoch. Pp. 263-303 in P. C. Holt, ed., *The distributional history of the biota of the Southern Appalachians. Part III: Vertebrates*. Virginia Polytechnic Institute and State University, Research Division Monograph 4.
- Handley, C. O., Jr. 1980. Mammals. Pp. 483-621 in D. W. Linzey ed., *Endangered and threatened plants and animals of Virginia*. Center for Environmental Studies, Virginia Polytechnic Institute and State University (title page dated 1979).
- Handley, C. O., Jr. 1991. Mammals. Pp. 539-616, figs. 307-331, pls. 210-229. in K. Terwilliger, coordinator, *Virginia's endangered species. Proceedings of a symposium*. McDonald and Woodward Publishing Company, Blacksburg, Virginia.
- Kirkland, G. L., Jr. 1990. Patterns of initial small mammal community change after clearcutting of temperate North American forests. *Oikos* 59:313-320.
- McCary, B. C. 1986. Early man in Virginia. Pp. 71-78 in J. N. McDonald and S. O. Bird, eds., *The Quaternary of Virginia---a symposium volume*. Virginia Division of Mineral Resources Publication 75.
- Pagels, J. F., and C. O. Handley, Jr. 1989. Distribution of the southeastern shrew, *Sorex longirostris* Bachman in western Virginia. *Brimleyana* 15:123-131.
- Rose, R. K. 1986. Late prehistoric and protohistoric large mammal zoogeography of Virginia. Pp. 79-88 in J. N. McDonald and S. O. Bird, eds., *The Quaternary of Virginia---a symposium volume*. Virginia Division of Mineral Resources Publication 75.



## Small Mammal Diversity in Forested and Clearcut Habitats in the Virginia Piedmont

John F. Pagels, Sandra Y. Erdle and Kristen L. Uthus

Department of Biology, Virginia Commonwealth University  
Richmond, Virginia 23284

Joseph C. Mitchell, Department of Biology,  
University of Richmond, Richmond, Virginia 23173

### ABSTRACT

A total of 754 small mammals representing 17 species was captured in clearcut/old field and mixed forest habitats in Cumberland County, Virginia. Species richness and diversity ( $H'$ ) were highest in clearcuts, and overall captures were twice as great in this habitat. Habitat generalists and edge/old field species represented 65% and 32%, respectively, of the total captures in the forested habitats. In the clearcuts, however, nearly the opposite was found: 59% were edge/old field forms, and 40% were generalists. Certain edge/old field forms, among them *Cryptotis parva*, *Reithrodontomys humulis* and *Microtus pennsylvanicus*, although captured in greater numbers in the clearcuts, were also captured in the forested habitats, indicating their ability to inhabit or disperse through atypical environments when corridors of preferred habitat are not present.

**Key Words:** Mammals, diversity, deforestation, Virginia Piedmont

### INTRODUCTION

Thirty-three species of mammals have been reported from the central Piedmont of Virginia exclusive of bats and introduced murine rodents (Handley and Patton, 1947; Pagels, 1977; Handley and Pagels, 1991). Twelve of the 33 are considered habitat generalists. Seven species occupy habitats near water, and 6 species are associated with woodlands. Many of the latter are squirrels. The remaining 8 species are colonizing or pioneer species associated with edge and old field habitats.

Because of current and historic landuse practices, Virginia's modern day landscape is a mosaic of habitat types (Silver, 1990). These include agricultural fields, old fields, mixed pine-hardwoods, pine monocultures, mixed hardwoods, riparian corridors, wetlands, and the interfaces among these habitats. Corridors connecting habitats allow colonization of new areas as old ones become unsuitable. Presumably, the precolonial landscape was also a mosaic of forest and isolated, temporary clearings resulting from windstorms, fire, and native American activities. There was certainly less nonforested land than there is today, and it was considerably more disjunct. Because certain small mammals have been found in greater numbers in early successional habitats than in older habitats (Kirkland, 1990), they have apparently benefitted from the clearing of closed canopy forests and the proliferation of old fields.

Due to the mixture of habitat generalists and specialists, small mammal community composition and diversity should vary among major habitat types. We examined these aspects of small mammal ecology in 2 highly contrasting habitats, old field and forest, in the central Piedmont of Virginia. Our objectives were to (1) compare species richness and diversity of small mammal communities in the 2 habitats, and (2) evaluate the impacts of tree removal (clearcutting) on forest communities in the Virginia Piedmont. We also use these results and insights to speculate on habitat use and relative population size of colonizing species before European settlers cleared large tracts of forest.

#### METHODS AND MATERIALS

Four study sites were located in northern Cumberland County, Virginia, 3-6 km SW of Columbia, Goochland County. The sites were approximately 65 km W of the Fall Line. Two clearcuts, herein designated clearcut north (CCN) and clearcut south (CCS), were 3 and 6 years of age, respectively. Total ground level vegetation, e.g. grasses, forbs, vines, shrubs and seedlings, was similar at CCN and CCS. Numbers of seedlings were greater at CCS, and the younger CCN was characterized by greater numbers of vines. The nearest forest to either clearcut sampling array was approximately 185 m. The 2 forest sites, herein designated forest north (FRN) and forest south (FRS) were both approximately 40 years old. The most abundant trees at FRN with a dbh  $\geq$  10 cm were red maple (*Acer rubra*, 22.1% of total), shortleaf pine (*Pinus echinata*, 18.6%), tulip poplar (*Liriodendron tulipifera*, 15.7%), white oak (*Quercus alba*, 10.7%) and American beech (*Fagus grandifolia*, 10.7%). At FRS the most abundant trees were sweet gum (*Liquidambar styraciflua*, 19.7%), tulip poplar (*Liriodendron tulipifera*, 16.7%), red maple (*Acer rubra*, 15.2%), white oak (*Quercus alba*, 12.1%), short leaf pine (*Pinus echinata*, 9.1%) and sycamore (*Platanus occidentalis*, 9.1%). Mean canopy openness, 14% at FRN and 25% at FRS, was reflected in greater numbers of vines and deciduous seedlings at the latter site. Small perennial streams were within 5 m of sampling arrays at the forested sites. The nearest clearcut to either forest site sampling array was approximately 165 m.

We sampled all sites with pitfall arrays based on a method modified from Campbell and Christman (1982). Each array consisted of 3 arms that radiated from a central point; the triad was open at the center and each arm was 5 m away from the center point. An arm consisted of a 5-m-long by 61-cm-high aluminum flashing drift fence with a 40 l bucket buried in the ground at each end. Pitfalls were open from September 1989 through September 1990; trapping effort totaled 2190 days in the combined clearcuts and 2346 days in the combined forested sites. We assumed that trappability of small mammals did not differ between the 2 habitat types, and that numbers captured reflected their actual relative abundance. A chi-square goodness of fit test was used to determine if differences existed in captures between habitat types; numbers of captures from a given habitat type were combined for the analyses. The Shannon Index ( $H'$ ) was used to calculate diversity. For further comparisons between habitat types, we classified each of the species captured into 1 of 4 categories: semi-aquatic (A), forest (F), old field/edge (O), and generalist (G) (Table 1). These categories were based on the habitat with which the species are typically associated as noted in the literature and in our

TABLE 1. Numbers of small mammals captured in pitfall-drift fence arrays in 2 mixed forest (FRN, FRS), and 2 clearcut/old field (CCN, CCS) habitats in Cumberland County, Virginia. See text for explanation of letters in parentheses.

Species	Sites				
	CCN	CCS	FRN	FRS	Total
<i>Didelphis virginiana</i>	(G)	0	1	0	1
<i>Scalopus aquaticus</i>	(G)	0	1	0	1
<i>Condylura cristata</i>	(A)	0	0	2	1
<i>Sorex longirostris</i>	(G)	26	37	5	18
<i>Sorex hoyi</i>	(G)	1	9	11	9
<i>Blarina brevicauda</i>	(G)	12	11	20	22
<i>Cryptotis parva</i>	(O)	64	23	4	6
<i>Glaucomys volans</i>	(F)	0	0	1	0
<i>Reithrodontomys humulis</i>	(O)	38	39	2	9
<i>Peromyscus leucopus</i>	(G)	41	56	39	27
<i>Ochrotomys nuttalli</i>	(G)	0	10	0	0
<i>Oryzomys palustris</i>	(A)	2	4	2	1
<i>Sigmodon hispidus</i>	(O)	4	19	0	0
<i>Microtus pennsylvanicus</i>	(O)	21	18	3	4
<i>Microtus pinetorum</i>	(G)	1	0	3	1
<i>Zapus hudsonius</i>	(O)	40	34	30	17
<i>Sylvilagus floridanus</i>	(O)	0	5	0	0
Total	250	267	122	115	754
Richness	11	14	12	11	17
Diversity ( $H'$ )	2.83	3.16	2.73	2.91	3.21
Evenness ( $H$ )	0.82	0.91	0.76	0.84	0.79

experiences. Specimens were deposited in the Virginia Commonwealth University Mammal Collection.

## RESULTS

Diversity and numbers of mammals captured were highest in the clearcuts; nearly 70% of 754 mammals were captured in this habitat type (Table 1). The total number and species composition of mammals captured within a given habitat type were similar (Table 1). Species richness was slightly higher in clearcut than in forested habitats. *Ochrotomys nuttalli* and *Sigmodon hispidus* were captured only in the clearcut habitat, along with the incidental captures of juvenile *Didelphis virginiana*, *Sylvilagus floridanus*, and a single *Scalopus aquaticus*. *Condylura cristata* and *Glaucomys volans* were trapped only in the forested habitats. Approximately 32% of 237 forest captures were species we classified as edge or old field forms; whereas, 59% of 517 clearcut captures were old field forms (Table 2). Chi-square analysis indicated that of the 10 species captured in both habitats, 7 were captured in significantly different numbers between habitat types ( $p < 0.05$ ). *Sorex longirostris*, *Cryptotis parva*, *Reithrodontomys humulis*, *Peromyscus leucopus*, *Microtus pennsylvanicus*, and *Zapus hudsonius* were captured in greater numbers

Table 2. Habitat associations of small mammals in the central Virginia Piedmont. Within each category for typical habitat association, the number of species (no. spec.), captures (no. caps.) and percent of those captures (% of caps.) in each habitat type are given.

Typical Habitat Association		Forests			Clearcuts		
		No. Spec.	No. Caps.	% of Caps.	No. Spec.	No. Caps.	% of Caps.
Generalist	(G)	5	155	65.4	8	206	39.8
Edge/Field	(O)	4	75	31.7	6	305	59.0
Semi-aquatic	(A)	2	6	2.5	1	6	1.2
Forest	(F)	1	1	0.4	--	--	--
Totals		12	237	100	15	517	100

in the clearcuts than in the forests, and *Blarina brevicauda* was captured in greater numbers in the forested habitats.

#### DISCUSSION

Results of this study increased our knowledge of the distribution of Virginia mammals. Our captures of the uncommon star-nosed mole (*Condylura cristata*) substantially increased the meager number of records for Virginia (Handley and Pagels, 1991). The rice rat (*Oryzomys palustris*), a semi-aquatic species common in coastal marshes, was taken in both habitat types. Our records in Cumberland County are the westernmost for *O. palustris* in Virginia (Webster et al., 1985).

Handley and Patton (1947) commented on the habitats of the few sites where *Zapus hudsonius* had been collected in the eastern half of Virginia. Later, Pagels (1980), who used snapback traps, noted that he had collected *Zapus* at only 1 site in 10 years of small mammal trapping in central Virginia. *Zapus* represented 16% of our 754 captures. Shrew captures accounted for approximately 37% of the total number of mammals taken. Our captures of *Sorex longirostris* equaled all known statewide captures as recently as 1989 (Pagels and Handley, 1989). Clearly, some of what we know about modern day diversity and abundance of Virginia mammals reflect years of sampling effort. Perhaps we encountered high population levels for certain species, e.g., *Zapus*; however, the numbers of captures of some species, e.g., shrews in general, also reflected the efficacy of pitfall trapping with drift fences.

Our results agree with those of numerous studies (see Kirkland, 1990) that found an increase in relative abundance of certain small mammals after clearcutting, with at least a portion of the increase being attributable to exploitation of the site by non-forest small mammals. Only *Sorex hoyi* and *Blarina brevicauda*, species that we categorized as generalists (Table 1), were taken in lower numbers in the clearcuts than in the forests. *Sigmodon hispidus*, a species categorized as an edge/old field form, was captured only in clearcut habitats, as was *Ochrotomys nuttalli*, a habitat generalist. Many of the differences in small mammal abundance between habitat types resulted from more captures of edge or old field forms in the clearcut habitat than in the forest habitat (Table 2). Generalists comprised a much greater percentage of the overall captures in the forest.

Because of the captures of old field forms in nearby forest habitats, we can suggest that their presence in clearcut habitats, as manifested both in species richness and abundance, was the result of both exploitation or colonization from nearby old fields and the "buried seed strategy" (Marks, 1974). The latter would be demonstrated by old field forms that existed in low numbers in the forests but that increased in numbers following the development of suitable habitat through clearing.

At the first symposium on threatened and endangered biota of Virginia, Pagels (1980) observed that although certain Virginia mammals had been extirpated or had diminished ranges, other species were now more common and widespread than several hundred years ago. Our data support Pagels' contention that such species are those associated with edge and old field situations. Concomitantly, small mammals characteristic of special habitat types are becoming increasingly rare. Because the area we studied lacks specialized habitats, e.g. caves or spruce forests, we found no species now considered threatened or endangered in Virginia. We predict that with continued clearing of closed canopy forests and landscape alterations due to urban development, species at home in edge/old field situations will continue to flourish, and that the "specialist forms", i.e. forest and semi-aquatic species, will decrease in numbers, if not disappear completely. What type of habitat mosaic will characterize our landscape in the future, and what species will dominate the mammal fauna? Inventories of selected urban communities could provide insight into these questions and lead to management options that may help to insure the long term survival of all of Virginia's small mammals.

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#### LITERATURE CITED

- Campbell, H. W., and S. P. Christman. 1982. Field techniques for herpetofaunal community analysis. pp. 193-200 in N. J. Scott, Jr. (ed.) Herpetological Communities, U. S. Fish and Wildlife Service Report 13, Washington, D. C.
- Handley, C. O., Jr., and J. F. Pagels. 1991. *Condylura cristata parva* Paradiso. Pp 565-567 in K. Terwilliger (coord.) Virginia's Endangered Species. McDonald and Woodward Publishing Co., Blacksburg, Virginia.
- , and C. P. Patton. 1947. Wild mammals of Virginia. Virginia Commission of Game and Inland Fisheries. Richmond, Virginia. 220 pp.
- Kirkland, G. L. 1990. Patterns of initial small mammal community change after clearcutting of temperate North American forests. Oikos 59: 313-320.

- Marks, P. L. 1974. The role of pin cherry (*Prunus pensylvanica* L.) in the maintenance of stability in northern hardwood ecosystems. Ecological Monographs 44: 73-88.
- Pagels, J. F. 1977. Distribution and habitat of cotton rat (*Sigmodon hispidus*) in central Virginia. Virginia Journal of Science 28: 133-135.
- \_\_\_\_\_. 1980. Mammals--The changing scene. pp. 603-609 in D. W. Linzey (ed.) Endangered and threatened plants and animals of Virginia. Center for Environmental Studies, Virginia Polytechnic Institute and State University, Blacksburg.
- \_\_\_\_\_, and C. O. Handley, Jr. 1989. Distribution of the southeastern shrew, *Sorex longirostris* Bachman, in western Virginia. Brimleyana 15: 123-131.
- Silver, T. 1990. A New Face on the Countryside. Cambridge University Press, New York. 204 pp.
- Webster, W. D., J. F. Parnell, and W. C. Biggs, Jr. 1985. Mammals of the Carolinas, Virginia, and Maryland. The University of North Carolina Press, Chapel Hill and London. 249 pp.

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## White-Tailed Deer as Keystone Species within Forest Habitats of Virginia

William J. McShea and John H. Rappole

National Zoological Park, Conservation & Research Center  
Front Royal, Virginia, 22630

### ABSTRACT

The 2 potential pathways by which deer may influence the abundance and distribution of other vertebrate species are, first, directly by competing for limited resources; and second, indirectly by altering habitat features that determine the distribution of other species. Evidence for direct competition may be consumption of mast by deer, while evidence for habitat alteration may be reduced understory vegetation densities within mature forests. Preliminary data indicate small mammal densities in the spring are limited by the size of the mast crop the previous autumn and composition of the understory bird community is correlated with the density of understory vegetation. The selected exclosure of deer from 4 study areas within the Shenandoah National Park and the National Zoo's Conservation and Research Center in Front Royal, Virginia will allow deer impacts along both these pathways to be assessed.

**Key Words:** White-tailed deer, *Odocoileus virginianus*, mast crop, forest under-story, forest birds, small mammals

### INTRODUCTION

Managing for the conservation of species on public lands is a primary policy concern (Johnson and Agee, 1988; Salwasser et al., 1984; Salwasser, 1988; Thomas and Salwasser, 1989). Within Virginia, both state and federal lands are set aside for the conservation of endangered and endemic species. Although the ultimate goal of conservation is relatively straightforward, problems arise for land managers when determining how best to meet this goal. With respect to the National Park Service, its mandate from Congress is to maintain the abundance, diversity and ecological integrity of native plants and animals (16 USC 1, 2-4). This mandate has been interpreted as allowing "nature to take its course", except when native species reach "unnaturally high densities" owing to human activities, and these densities have a negative impact on the historical or biological integrity of the park (National Park Service, 1988). White-tailed deer are presently at historically high densities within most of the eastern U.S. (McCabe and McCabe, 1984), but there is no firm evidence for stating that these high densities are negatively affecting the integrity of the biotic community within National Parks (Warren, 1991). The question of whether to manage white-tailed deer within public lands has been the focus of symposia by the National Park Service (Atlanta 1988), The Wildlife Society (Denver 1990) and USDA Forest Service (Warren, Pa. 1987). However, discussion of managing white-tailed deer within public lands set aside for conservation is prema-

ture without a better data base to determine the actual impact of this species on its community.

The potential role of white-tailed deer in forest communities expands the concept of "keystone" predator (Paine, 1974) to "keystone" species, i.e., species which by their behavior, and sometimes sheer numbers, have a significant impact on the diversity of species within ecosystems (Paine, 1980; Krebs, 1988; Terborgh, 1988). Large herbivores are frequently cited as keystone species because of their potential for alteration of habitat (Laws et al., 1975; Mack and Thompson, 1982; Krebs, 1988); thus white-tailed deer should be studied as a keystone species in eastern North America. White-tailed deer cause significant habitat alteration (Leopold, 1933; Hough, 1965; Alverson et al., 1988) and consume limited food resources (Pekins and Mautz, 1987); yet, beyond interactions with other large herbivores (Ludewig and Bowyer, 1985), their influence on vertebrate species composition within forest ecosystems has not been studied. It is necessary to test the hypothesis that white-tailed deer affect the composition of bird and mammal communities *indirectly* through altering habitat features, and *directly* through the consumption of shared food types (e. g. mast).

Mast is an important food resource for many forest mammals (Martin et al., 1951); reproduction and overwinter survival of both sciurids (Elliot, 1978; Nixon and Hanson, 1987) and white-footed mice (Miller and Getz, 1977; Gashwiler, 1979) are influenced by the size of the mast crop. Deer consume a significant portion of the mast crop within this study area (McShea and Schwede, 1992). This study showed that rapid declines in acorns on the ground occurred regardless of the size of the mast crop, and that deer increased their home range to incorporate mast producing areas and consumed approximately 50% of marked acorns placed out during the mast fall (McShea and Schwede, 1992). If the abundance of mast-consuming small mammals is positively correlated with the size of the mast crop, then high densities of white-tailed deer may restrict the ability of more mast-dependent species to survive low or moderate mast crop years.

The diversity of bird communities is influenced by both vertical (MacArthur and MacArthur, 1961) and horizontal (Roth, 1981) structural complexity. Within forests, the heterogeneity of understory vegetation is positively correlated with bird species diversity (Lynch and Whigham, 1984). Increased understory vegetation may increase the number of foraging niches available (MacArthur and MacArthur, 1961; Blake, 1983), and reduce the rate of nest predation by better concealing nests (Wray and Whitmore, 1979; Redmond et al., 1982; Martin and Roper, 1988) or hindering the movement of predators (Bowman and Harris, 1980).

It is well documented that white-tailed deer reduce understory density and diversity (Alverson et al., 1988; Hough, 1965; Tilghman, 1989), and circumstantial evidence indicates deer foraging may alter the bird community dependent on that understory. A 42% decline over a 50 year period in the number of bird species which nest within 2 m of the forest floor in a western New York preserve has been attributed to high deer densities (Baird, 1990), as have low ovenbird densities within a preserve in western Maryland (Boone and Dowell, 1986). In Pennsylvania, a forest enclosure with artificially high densities of ungulates had a lower diversity of bird species and was composed of more "field" species relative to a control area (Casey and Hein, 1983). Also in Pennsylvania, forest areas with logging activity

maintained a more diverse bird community than areas with high densities of white-tailed deer (Dessecker and Yahner, 1987).

Over a long period, reduced deer densities may have wide ranging effects on the small mammal and bird communities within mature forests, possibly by changing the diversity and density of overstory vegetation. However, we predict that, if deer affect the vertebrate community, the initial response to lower deer densities will be increased understory vegetation and increased mast crop availability. Therefore, we will examine 2 subsets of the vertebrate community which should respond to these environmental changes; mast-dependent small mammals and forest interior birds that nest and/or forage within 2 m of the forest floor.

The objective of this paper is to examine the vertebrate community within a tract of continuous forest in the southern Appalachian region of Virginia for evidence that present densities of deer have a negative impact on select vertebrate communities within this region. We are addressing 2 potential effects (indirect and direct) and focusing on specific portions of the vertebrate community which would best test each effect (mast consuming small mammals and forest understory birds).

#### METHODS

Study sites are located in mature, Appalachian oak forest on the premises of the Conservation and Research Center (CRC) and Shenandoah National Park (SNP) in northern Virginia. The CRC is a 1,200-ha research facility located 2 km SE of the town of Front Royal, Warren County. The SNP is a component of the national park system that stretches along the Appalachian Mountain chain from Front Royal south almost to Waynesboro, Virginia, a distance of approximately 160 km. Deer densities within the CRC and sections of the SNP are high (0.3 deer/ha) (Seidensticker, 1983), and have been at these levels for at least the last 5 years. This high deer density is comparable to other state and federal lands (Wilcox, 1976; Healy et al., 1987).

Five study sites are located in the northern section of SNP and 3 sites are located within the adjacent CRC. The sites are located more than 1 km apart, in mature (>40 years), hardwood forest with mast producing trees in overstory, and not within designated wilderness areas of SNP or captive breeding areas at CRC. Each site is 4 ha, and composed of 100 small mammal trapping stations at 20-m intervals. Two sites, both in CRC, have been monitored since 1986, the remaining sites were established in 1990.

In order to estimate mast production at each grid, every other station has a mast collector (230 cm circumference wire-mesh funnel), which was examined weekly during September and October. All acorn and hickory nuts were removed, air dried for a month, separated from their caps or shells, and weighed to the nearest gm (See McShea and Schwede, 1992, for more details).

To assess the impact of mast crops on small mammal populations, overwinter survival, as measured by population densities in late March, was compared to size of the mast crop the previous autumn. Small mammal density was estimated by trapping for 72 h at each site; 2 Sherman traps (23 cm) were placed at each station (200 total) and checked every 12 h. To monitor squirrel densities, 10 Tomahawk traps (40 cm) were placed on each site at 50-m intervals. All captured animals were uniquely marked, weighed, and examined for evaluation of reproductive condition.

The data presented in this paper are from only 2 small mammal populations, both in CRC, which were monitored from 1986 through 1990. The number of small mammals which consume mast that were captured was multiplied by the estimated daily mast requirements for each species (*Peromyscus*, 2 acorns/day, Verme, 1957; *Tamias*, 4 acorns/day, Verme, 1957, Elliot, 1978; *Glaucomys*, 4 acorns/day, Weigel, 1978; *Sciurus*, 8 acorns/day, Nixon and Hansen, 1987); the sum was considered the estimated daily mast needs for the mast-dependent community within the study areas.

The avian understory community was sampled with mist-nets during June 1990. On each grid nets were placed every 50 m (5 lines of 5 nets), so as to cover the entire site. Each captive was aged, sexed, weighed, checked for molt and subcutaneous fat reserves, and banded with a U.S. Fish and Wildlife Service band. Two sites were netted during each 1 week period of the breeding season (June 1 - July 1) for a total of 1,500 net hours (12 hours x 25 nets x 5 days) at each site. We monitored all bird populations, but focused our efforts on species which nest and/or forage within 2 m of the forest floor (Table 1). The abundance of this particular guild of birds should closely reflect understory composition.

As a preliminary measure of activity of deer on the grids, in November 1990 we established a series of remote tripcameras on 2 grids with markedly different understory densities (Elk and Range grids). The 35 mm auto-focus camera, with wide angle lens and built-in flash, is connected to an infrared sensor which detects changes in "heat profile" (CAM-TRAKKER, Dan Stoneburner, Athens GA). Three trip-cameras were placed 60 m apart on each grid and set for 1 week. If a camera ceased functioning during the week, a day/time stamp placed on each photograph determined the last day the camera monitored an area and allowed a calculation of "camera days" for each grid (sum of cameras operating on each day of sample; maximum n for each grid = 21). The cameras also possess a 3-minute delay between photos to reduce repeated photos of a single animal. The trip-cameras cannot differentiate between individuals and hence cannot be used to determine density, but they give an estimate of animal activity within each study area. The amount of deer activity in an area was expressed as number of deer photographed per "camera day".

Habitat variation was sampled within three 576-m<sup>2</sup> (24 X 24 m) plots at each site, and emphasized the density and diversity of forest understory and ground cover. The specific protocol was developed by SNP officials, and is presently used as part of their long-term environmental monitoring program (SNP 1990). Measurements of understory within each plot included counting and identifying all woody stems, estimating density through use of a "cover board" (Nudds, 1977), and counting and identifying all woody seedlings in 12 1-m plots within each larger plot. The coverboard was a 2-m board with 100 squares equally divided into 4 quadrats. For each 24 x 24 m plot observers recorded the number of squares which contained vegetation when sighted from the center of the plot to each of the corners. For understory density, we used the mean number of cells covered by vegetation for the portion of the board between 0.5 and 1.5-m in height. The relationship between understory density and bird populations, and between small mammal populations and mast crop, was tested with Pearson product-moment correlation coefficients, where significance was considered P < 0.05.

TABLE 1. Bird species that nest and/or forage within 2 m of forest floor within the central-Atlantic region of North America (Ehrlich et al., 1988; Terre, 1980).

Kentucky Warbler	<i>Oporornis formosus</i>
Louisiana Waterthrush	<i>Seiurus motacilla</i>
Ovenbird	<i>Seiurus aurocapillus</i>
Veery	<i>Catharus fuscescens</i>
Worm-eating Warbler	<i>Helmintheros vermivorus</i>
Hooded Warbler	<i>Wilsonia citrina</i>
Wood Thrush	<i>Hylocichla mustelina</i>
Rufous-sided Towhee*	<i>Pipilo erythrophthalmus</i>
Northern Cardinal*	<i>Cardinalis cardinalis</i>
Gray Catbird*	<i>Dumetella carolinensis</i>

\* species which also occur in early successional forests, but are expected to respond to increased understory density.

## RESULTS

**Small Mammals:** The density of the mast-dependent small mammal community in the spring was positively correlated with the mast crop production during the previous autumn ( $r = 0.76$ ,  $n = 6$ ,  $P < 0.05$ ), but mast production beyond 150 kg/ha does not appear to have a significant impact on small mammal densities (Figure 1). As a test for possible correlation between mast production and severity of winter, mammals that do not consume mast (*Blarina* and *Sorex*) showed no significant correlation between spring densities and mast production the previous autumn ( $r = 0.12$ ,  $n = 6$ ,  $P > 0.10$ ).

**Bird Community:** There was a significant positive correlation between the understory density, as measured by the coverboard, and both the number of individuals and the number of species captured (Table 2). Within the guild of understory birds there was also a significant increase in the number of species captured with increasing understory density, as measured by both the coverboard and the number of woody stems (Table 2).

**Deer Density:** There were almost twice as many deer photographed on the low-density understory grid, as on the high-density understory grid (1.29 deer photographed/camera day and 0.70 deer photographed/camera day, respectively; 17 and 20 cameras days, respectively).

## DISCUSSION

Estimates of mast crop requirements for wildlife range from 100 to 200 kg/ha (Goodrum et al., 1971; French, 1980; Johnson et al., 1989). For this study, at densities below 150 kg acorns/ha there was a positive correlation between mast crop size and the overwintering population of mast-consuming small mammals. The lack of a significant correlation between mast crop and nonmast-consuming small mammals indicates that severity of winter, or some other environmental factor correlated with mast crop, was probably not responsible for the results. Above acorn densities of 150 kg/ha, it is not known whether mast is no longer limiting, or small mammals cannot effectively exploit the large mast crop before the deer. Deer

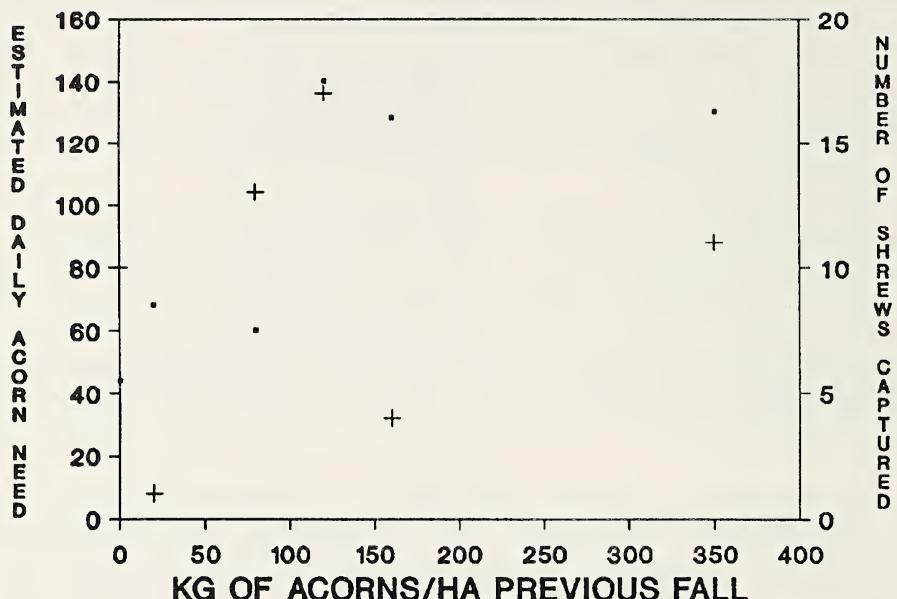


FIGURE 1. The relationship between spring densities of small mammals and the size of the acorn crop the previous autumn. Two groups of small mammals are shown, those rodents which consume acorns (●) and small insectivorous shrews which do not consume acorns (+). Individuals within the acorn-consuming small mammal population are weighted by the amount of acorns each species was estimated to consume each day (see methods).

TABLE 2. Understory and bird community characteristics of each study grid during summer 1990. The correlation coefficients (*r*) between bird community measures, and number of woody stems (*r*1) and coverboard measures (*r*2) are given at bottom of table.

Grid	Number of Species	Number of Individuals	Understory Bird Guild <sup>2</sup>	Number of Woody Stems	Coverboard <sup>1</sup>
Elk	13	35	2	101	3.8
Dump	13	30	3	52	4.1
Posey	12	47	3	222	4.3
Hilltop	18	45	2	146	6.2
Bear	12	45	3	330	9.7
Range	23	103	7	296	14.2
Keyser	18	67	6	3 86	15.8
AT	22	68	6	804	16.9
r1	0.59	0.50	0.65*		
r2	0.78**	0.78**	0.90**		

<sup>1</sup> see TABLE 1

<sup>2</sup> mean number of squares covered by vegetation

\* P < 0.05

\*\* P < 0.01

consume acorns at a rate of approximately 1 acorn/minute (McShea and Schwede, 1992). Slower search and handling times for sciurids and mice (Verme, 1957; Elliot, 1978) may limit their ability to store more mast within the period before the mast crop is eaten by deer.

The bird community was larger with increased understory density. This was particularly evident for the guild of birds that nest or forage within the understory. Deer do shape the composition and density of the understory (Hough, 1965; Alverson et al., 1988). The higher density of deer within the grid with the low density of understory supports the hypothesis that deer may have an indirect impact on bird communities within deciduous forests.

This paper presents preliminary evidence for the impact of deer on forest vertebrate communities, but the data only suggest an impact through correlation. Manipulation of deer density within the study areas must be made to test the correlations. We are presently constructing deer exclosures around 4 study grids, with 4 grids left as controls. It may take several years to detect any changes which might occur within the exclosures; however, at the conclusion of the project we will be able to quantify the effect of reduced deer density on our 2 study groups.

The densities of deer within these study areas are high. There is no evidence that the deer population will soon "crash" because of these densities, or that any other form of natural regulation will reduce deer densities during the immediate future. There is nothing inherently wrong with high deer densities, the question for land managers is how compatible these high densities are with other conservation goals. We do not identify white-tailed deer as a negative factor within forest communities, but as a keystone component within their community, which should be viewed as an integral part of any land management. Decisions to increase or decrease populations of specific species within the vertebrate community (e. g. neotropical migrant birds) must consider the role of white-tailed deer in their ecology.

The challenge of land management in Virginia will be to increase populations of endangered and endemic species, while preserving what are essentially our success stories of abundant wildlife species.

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#### LITERATURE CITED

- Alverson, W. S., D. M. Waller, and S. I. Solheim. 1988. Forests too deer: edge effects in northern Wisconsin. *Conservation Biology*, 2:348-358.
- Baird, T. H. 1990. Breeding Bird Populations. *New York State Museum Bulletin* # 477. S.U.N.Y. Albany, N.Y. 41 pp.
- Blake, J. E. 1983. Trophic structure of bird communities in forest patches in east-central Illinois. *Wilson Bulletin* 95:416-430.
- Boone, D. D. and B. A. Dowell. 1986. Catoctin Mountain Park Bird Study. National Park Service CX-3000- 4-0152. 22 pp.

- Bowman, G. B. and L. D. Harris. 1980. Effect of habitat heterogeneity on ground nest depredation. *Journal of Wildlife Management* 44:806-813.
- Casey, D. and D. Hein. 1983. Effects of heavy browsing on a bird community in a deciduous forest. *Journal of Wildlife Management* 7:829-836.
- Dessecker, D. R. and R. H. Yahner. 1987. Breeding bird communities associated with Pennsylvania northern hardwood clearcut stands. *Proceedings Pennsylvania Academy of Science* 61:170-173.
- Ehrlich, P. R., D. S. Dobkin and D. Wheye. 1988. *The Birder's Handbook*. Simon & Schuster Inc. New York, 785 pp.
- Elliot, L. 1978. Social biology and foraging ecology of the eastern chipmunk (*Tamias striatus*) in the Adirondack mountains. *Smithsonian Contributions to Zoology* 265:1-107.
- French, J. R. 1980. Oak mast availability and use by large mammals in Eastern Tennessee. M. S. Thesis. University of Georgia, Athens.
- Gashwiler, J. S. 1979. Deer mouse reproduction and its relationship to the tree seed crop. *American Midland Naturalist* 102:95-104.
- Goodrum, P. D., V. H. Reid, and C. E. Boyd. 1971. Acorn yields, characteristics and management criteria of oaks for wildlife. *Journal of Wildlife Management* 35:520-532.
- Healy, W. M., R. T. Brooks, and P. J. Lyons. 1987. Deer and forests on Boston's municipal watershed after 50 years as a wildlife sanctuary. Pages 3 - 21, in Marquis, D. D., ed. *Proceedings Deer, Forestry & Agriculture: Interactions and Strategies for Management*. Allegheny Society American Forestry, Warren, Pennsylvania.
- Hough, A. F. 1965. A twenty-year record of understory vegetational change in a virgin Pennsylvania forest. *Ecology* 46:370-373.
- Johnson, D. R. and J. K. Agee. 1988. Introduction to ecosystem management. Pages 3-14, in Agee, J. K. and D. R. Johnson, eds. *Ecosystem Management for Parks and Wilderness*. University of Washington Press, Seattle.
- Johnson, S. A., J. M. Wentworth, and P. E. Hale. 1989. Cumulative mast needs of forest wildlife. Pages 18-23 in McGee, C. E. ed. *Proceedings workshop on southern Appalachian mast management*. Knoxville, Tennessee.
- Krebs, C. J. 1988. *The Message of Ecology*. Harper & Row, New York, 278 pp.
- Laws, R. M., I. S. C. Parker, and R. C. B. Johnston. 1975. *Elephants and their habitats*. Clarendon Press, London, 371 pp.
- Leopold, A. 1933. *Game management*. Charles Scribner's Sons, New York. 481 pp.
- Ludewig, H. A. and T. R. Bowyer. 1985. Overlap in winter diets of sympatric moose and white-tailed deer in Maine. *Journal of Mammalogy* 66:390-392.
- Lynch, J. F. and D. F. Whigham. 1984. Effect of forest fragmentation on breeding bird communities in Maryland. *Biological Conservation* 8:287-324.
- MacArthur, R. H. and J. W. MacArthur. 1961. On bird species diversity. *Ecology* 42:594-598.
- Mack, R. N. and J. N. Thompson. 1982. Evolution in steppe with large hoofed mammals. *American Naturalist* 119:757-773.
- Martin, A. C., H. S. Zim, and A. L. Nelson. 1951. *American Wildlife and Plants*. Dover Publications New York. 500 pp.

- Martin, T. E. and J. J. Roper. 1988. Nest predation and nest-site selection of a western population of the Hermit Thrush. *Condor* 90:51-57.
- McCabe, R. E. and T. R. McCabe. 1984. Of slings and arrows: an historical retrospection. Pages 19-72 in Halls, L. K. ed. *White-tailed deer: ecology and management*. Stackpole Books, Harrisburg, Pennsylvania.
- McShea, W. J. and G. Schwede. 1992. The interrelationships of mast, white-tailed deer and other mast consumers. *Journal of Mammalogy* 73: in press.
- Miller, D. H. and L. L. Getz. 1977. Factors influencing local distribution and species diversity of forest mammals in New England. *Canadian Journal of Zoology* 55:806-814.
- Nixon, C. M. and L. P. Hansen. 1987. Managing forests to maintain populations of gray and fox squirrels. *Illinois Department Conservation Technical Bulletin* # 5, 35 pp.
- Nudds, T. D. 1977. Quantifying the vegetation structure of wildlife cover. *Wildlife Society Bulletin* 5:113-117.
- Paine, R. T. 1974. Intertidal community structure. Experimental studies on the relationship between a dominant competitor and its principal predator. *Oecologia* 15:93-120.
- Paine, R. T. 1980. Food webs: linkage, interaction strength and community infrastructure. *Journal of Animal Ecology* 49:667-685.
- Pekins, P. J. and W. W. Mautz. 1987. Acorn usage by deer: significance to oak management. *Northern Journal of Applied Forestry* 4:124-128.
- Redmond, G. W., D. M. Keppie, and P. W. Herzog. 1982. Vegetative structure, concealment, and success at nests of two races of spruce grouse. *Canadian Journal of Zoology* 60:670-675.
- Roth, R. R. 1976. Spatial heterogeneity and bird species diversity. *Ecology* 57:773-782.
- Salwasser, H. 1988. Managing ecosystems for viable populations of vertebrates: a focus for biodiversity. Pages 87-104, in Agee, J. K. and D. R. Johnson eds. *Ecosystem Management for Parks and Wildernesses*. University of Washington Press, Seattle.
- Salwasser, H., J. W. Thomas, F. Samson. 1984. Applying the diversity concept to national forest management. Pages 59-69 in Cooley, J. L. and J. H. Cooley eds. *Natural Diversity in Forest Ecosystems*. Institute of Ecology, University of Georgia, Athens.
- Seidensticker, J. 1983. Management of white-tailed deer at the National Zoological Park's Conservation and Research Center. *International Zoological Yearbook* 23:234-236.
- Shenandoah National Park. 1990. Long term environmental monitoring system. Section 2: Forest component users manual. NPS/NRSHEN/NRTR-90/02. Natural Resources Publ. Denver, Colorado 30 pp.
- Terres, J. K. 1980. *The Audubon Society Encyclopedia of North American Birds*. Knopf Publishers, New York. 785 pp.
- Terborgh, J. 1988. The big things that run the world - a sequel to E. O. Wilson. *Conservation Biology* 2:402-403.
- Tilghman, N. G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. *Journal of Wildlife management* 53:524-532.

- Thomas, J. W. and H. Salwasser 1989. Bringing conservation biology into a position of influence in natural resource management. *Conservation Biology* 3:123-127.
- U. S. National Park Service. 1988. Management policies. Part I: management of the national park system. U. S. National Park Service, Washington D. C.
- Verme, L. J. 1957. Acorn consumption by chipmunks and white-footed mice. *Journal of Mammalogy* 38:129-132.
- Warren, R. J. 1991. Ecological justification for controlling deer populations in eastern National Parks. Pages 56 - 66 in *Transactions 56th North American Wildlife and Natural Resources Conference*, Edmonton, Canada.
- Weigel, P. D. 1978. Resource overlap, interspecific interactions and the distribution of the flying squirrels, *Glaucomys volans* and *G. sabrinus*. *American Midland Naturalist* 100:83-96.
- Wilcox, S. W. 1976. Deer production in the United States, 1969-1973. Arizona State University Press, Tempe. 48 pp.
- Wray, T. and R. C. Whitmore. 1979. Effects of vegetation on nesting success of vesper sparrow. *Auk* 96:802-805.

## The Effects of Habitat Fragmentation and Loss on Dismal Swamp Mammals

Robert K. Rose, Department of Biological Sciences,  
Old Dominion University, Norfolk, Virginia 23529-0266

### ABSTRACT

In the 1890's, 5 new species of small mammals were described from the Great Dismal Swamp of Virginia and North Carolina. Although since relegated to subspecies status, these taxa seem to have developed during the Holocene in association with the emergence of the Dismal Swamp. The Dismal Swamp, a forested wetland with a mosaic of vegetation types, formerly extended from the James River to the Albemarle Sound but has been shrinking since the 18th Century due to efforts to drain the land for cultivation. More recently, much of the historic Dismal Swamp has been fragmented into cities, subdivisions and industrial parks, and although more than 47,000 ha has been placed in a national wildlife refuge, habitat loss continues there through biological succession. Thus, the distinctive mammalian taxa of the region, together with disjunct populations of species of larger mammals, are threatened by habitat loss via destruction, succession, or fragmentation, and for some, interbreeding with upland subspecies.

**Key Words:** Dismal Swamp, distribution, endemic mammals, shrews, status, threats, wetlands.

### INTRODUCTION

Four taxa of small mammals were described from specimens collected between 1895-1898 near Lake Drummond in the Dismal Swamp of Virginia (Handley, 1979), and a fifth species, a meadow vole, was described from a section of the Dismal Swamp in North Carolina (Rhoads and Young, 1897). These mammals are: *Blarina [brevicauda] telmalestes*, the Dismal Swamp short-tailed shrew; *Sorex [longirostris] fisheri*, the Dismal Swamp southeastern shrew; *Microtus [pennsylvanicus] nigrans*, the darkest race of meadow vole; *Ondatra [zibethicus] macrodon*, a large-toothed muskrat; and *Synaptomys [cooperi] helaleutes*, the Dismal Swamp southern bog lemming. All 5 taxa were originally described as distinctive species but later taxonomic revisions have reduced these taxa to subspecies of the species shown in brackets.

Later studies revealed that *M. p. nigrans* and *O. z. macrodon* have distributions in coastal Virginia and North Carolina that extend well beyond the boundaries of the Dismal Swamp. However, the other 3 taxa, particularly the Dismal Swamp southeastern shrew and Dismal Swamp southern bog lemming, seemingly are restricted to the historic Dismal Swamp. (The distribution of *Blarina brevicauda telmalestes* is less well understood but probably now extends beyond the boundaries of the historic Dismal Swamp.) Thus, it is fair to assume that these 3 taxa of small mammals somehow have developed in association with the formation of the Dismal Swamp and are adapted to the Dismal Swamp environments. Although it is unclear how a swamp could serve as an isolating force or mechanism to separate

swamp from upland populations and thereby permit genetic and evolutionary divergence, the distributional evidence supports that viewpoint. Furthermore, if species have evolved in association with the Dismal Swamp, it is fair to assume that they are highly adapted to that environment and may have difficulty in surviving different conditions. Thus, the loss of Dismal Swamp habitat, by whatever means, poses a threat to these Dismal Swamp mammals.

Both shrews show a feature that is typical of small mammals on islands, i.e., they are larger than individuals from the nearby "mainland" (here, upland) subspecies. The Dismal Swamp southeastern shrew is about 25 % longer than the upland subspecies, *Sorex longirostris longirostris*, whereas the Dismal Swamp short-tailed shrew is 15-20% longer and often is 2-3 times heavier than small upland *Blarina*, now called *B. carolinensis*, the southern short-tailed shrew. Individuals of the latter species from the region weigh 6-8 g, and usually measure less than 100 mm. Thus, the size differences between Swamp shrews and upland shrews are striking, and in this regard too the Dismal Swamp seems to be acting as a biological island.

The purpose of this paper is to describe what is known about the present distributions of the Dismal Swamp endemics and to evaluate how the changes in land-use patterns now occurring in the region might alter the status and distribution of these and other Dismal Swamp mammals. Specifically, the swampland forests, seemingly crucial to the continued existence of these Dismal Swamp mammals, are disappearing at a steady rate, despite both laws protecting wetlands and the best efforts of state and federal agencies to acquire large tracts of Dismal Swamp and place them in reserves and refuges.

#### BACKGROUND AND REVIEW

The Great Dismal Swamp of eastern Virginia and North Carolina is a large forested wetland that has resisted more than 2 centuries of attempts to drain and convert the land to agriculture or other purposes. The primary reason for these failures relates to an impermeable fossiliferous clay, the Yorktown Formation, deposited during an early Miocene transgression (Oaks and Whitehead, 1979), that underlies 5 more permeable lagoonal deposits of Pleistocene age. Believed to have originated during the Sangamon Interglacial period of the Pleistocene, the Dismal Swamp slopes gently to the east from its discrete western boundary, the Suffolk Escarpment. Mean elevation in the Dismal Swamp falls approximately 20 cm per km to lowest elevations at the Deep Creek Swale and Fentress Rise, the old dune lines that form the more poorly defined eastern boundary. Thus, a combination of geological and topographical factors, particularly sub-surface layers and the natural drainage barriers, has created swamp that resists draining only in this section of the Mid-Atlantic Coastal Plain. The Dismal Swamp is unusual because it is "a finger of palustrine forest of the Coastal Plain, extended north yet oriented south because of high temperatures, high humidity, and a long growing season (Murray, 1965)."

Core samples collected throughout the Dismal Swamp have provided a history of plant succession through both pollen analysis and the distribution of peaty soils (Whitehead and Oaks, 1979). Swamp formation probably began along stream courses with the beginning of the retreat of the Wisconsinan glacier, about 11,000 to 12,000  $^{14}\text{C}$  years ago. By 10,600  $^{14}\text{C}$  years ago, the spruce-pine forest of the late

Pleistocene had been replaced by a variety of species typical of northern hardwood forests, which in turn was replaced (by 8200  $^{14}\text{C}$  years ago) by oaks, hickories and deciduous species of present forests in the Southeast. The peat marsh then was confined to stream beds until about 6,000  $^{14}\text{C}$  years ago, when it progressed inland and laterally across drainage divides. At this time, some southern swamp forest species were appearing, and peaty elements in the soils indicated an extended hydroperiod, producing swampy conditions. During the next 2,500 years, peat layers developed to cover virtually the entire Dismal Swamp, forests changed to the cypress-gum domination of today, and the water table was at or above the surface for significant periods each year. Thus, the present vegetation and conditions of the Dismal Swamp date from about 3,500  $^{14}\text{C}$  years ago, making this habitat a young feature in the region. The cypress-gum forest has been variable both spatially and temporally during these 3,500 years as a result of peat depth, fluctuations in water table, fires, and more recently by draining, logging, and other human disturbances. The Dismal Swamp at the time of settlement by Europeans was a mosaic of habitat types, including large tracts of Atlantic white cedar (*Chamaecyparis thyoides*), bald cypress (*Taxodium distichum*), cane (*Arundinaria gigantea*), probably with pond pine (*Pinus serotina*) and loblolly pines (*Pinus taeda*) on drier sites. Small patches (usually 1 ha) of slightly higher and drier habitat formed mesic islands (G. Levy, pers. comm.) that supported beeches and similar trees that are typical of upland forests in southeastern Virginia.

The former extent of the Dismal Swamp at the time of settlement by Europeans may never be known, but it probably stretched southward from the Chesapeake Bay (Norfolk) to the Albemarle Sound in North Carolina, and from the James River and its tributaries eastward to coastal dunes of different ages near the Atlantic Ocean. Fingers of swamp habitat along rivers or streams sometimes extended beyond the contiguous Dismal Swamp that was estimated to have been as large as 6,200 km<sup>2</sup> (Kearney, 1901). Low-lying swamp forests along the Northwest and Pasquotank Rivers and their feeder creeks are examples of these extensions from the core area of the Dismal Swamp.

#### LOSS OF DISMAL SWAMP HABITAT DUE TO HUMAN ACTIVITIES

During the 18th Century there were numerous development schemes to try to convert sections of the Dismal Swamp into farmland. George Washington was a member of a land company that sought to develop the Dismal Swamp for agriculture, and in 1768 he directed that a survey of an eastbound road ending at Lake Drummond be made. Washington Ditch, and many other ditches dug by slave labor, served the dual purpose of providing a waterway on which to float commercially valuable logs and an adjacent roadway (created by placement of the spoil from the ditch) for the mules or oxen that pulled those rafts of logs. Linking such ditches with those draining to the east served to help drain the water from the Swamp. Elsewhere in the mid-Atlantic coastal plain, these techniques were successful but these methods always failed in the Dismal Swamp, due to the impervious clays in the subsoils. When the cleared land finally was abandoned, it inevitably returned to swamp forest. Later, logging companies dug more ditches and made more roads (and even built narrow-gauged railways) as they exploited the large tracts of cypress and Atlantic white cedar, both important trees in

shipbuilding and as construction materials for the emerging cities and industries in the region (Frost and Musselman, 1987).

In 1812, the Dismal Swamp Canal was completed by the U. S. Army Corps of Engineers. Lying on the east side of the Dismal Swamp and now running parallel to US Route 17, this canal linked Norfolk with agricultural and commercial enterprises in coastal North Carolina. Later, a "feeder ditch" was constructed to connect Lake Drummond to the Dismal Swamp Canal; this scheme was designed to add water to the canal during periods of low flow. Regrettably, the engineers had neglected to plumb Lake Drummond, which despite its 1000-ha area has a mean depth of 1.3 m and hence has scarcely enough water to change the flow in the Dismal Swamp Canal. Even if the lake was 3 or 4 times deeper early in the 19th Century (as some notes from the period indicate), the volume of water in the lake is too small to raise water levels in the canal significantly. This withdrawal of water from Lake Drummond has helped lower the water table and hasten the drying of the Dismal Swamp, and therefore has contributed to the changes in vegetation.

Thus, in the last 200-300 years the extent of Dismal Swamp forests has shrunk considerably and the remnants have changed from a patchwork of Atlantic white cedar, bald cypress, and cane to forest increasingly dominated by red maple (*Acer rubrum*) and black (*Nyssa sylvatica*) and water gums (*N. aquatica*). Besides the changes in water table due to ditches and construction of the Dismal Swamp Canal, fire suppression and soil subsidence also have modified the swamp environment, thereby directly or indirectly influencing the biota, including the mammals. Recognizing the unusual biological features of the Dismal Swamp, the US Fish and Wildlife Service (USFWS) established the Great Dismal Swamp National Wildlife Refuge (GDSNWR) in 1974, using a large tract donated by the Union Camp Corporation as the core area.

#### THE DISMAL SWAMP MAMMAL FAUNA

The first collections of mammals were made in the Dismal Swamp during the 1895-1898 period by teams of investigators from the U. S. Department of Agriculture's Bureau of Biological Surveys. According to Handley (1979), who examined field notes and unpublished reports, the teams, headed by A. K. Fisher and Wm. Palmer, spent a total of 23 weeks making collections which were sent back to the Smithsonian Institution for identification and accession. The large shrews from the Dismal Swamp were described as new species (*Blarina [brevicauda] telmalestes* and *Sorex [longirostris] fisheri*) by C. Hart Merriam (1895a, 1895b), considered to be the father of American mammalogy and then the Director of the Bureau of Biological Surveys. Merriam (1896, 1897) described more of Fisher's collections from the Lake Drummond region when he named new species of southern bog lemming (*Synaptomys [cooperi] helaleetes*) and of muskrat (*Ondatra [zibethicus] macrodon*), respectively.

Recently, the statuses of some Dismal Swamp taxa were questioned (Handley, 1979, 1980) because no specimens of Dismal Swamp southern bog lemming and only 1 specimen of Dismal Swamp southeastern shrew had been collected in this century. However, lines of pitfall traps set by Rose (1981a, 1981b) yielded 7 *Synaptomys* and 15 *Sorex longirostris* from locations near Jericho and East Ditches in the northwest corner of the GDSNWR. These findings led to a longer study of

Dismal Swamp mammals (Rose, 1983) that focused on these 2 species but also provided information about other small mammals too (Rose et al., 1990). The 3 Dismal Swamp endemics (Dismal Swamp subspecies of southeastern shrew, short-tailed shrew, and southern bog lemming) were the most numerous species taken in the pitfall traps. Some species, such as the eastern harvest mouse, *Reithrodontomys humulis*, were found to be far more common than previously believed, and 1 species, the hispid cotton rat, *Sigmodon hispidus*, was recorded for the first time from the Dismal Swamp. These studies, which used live trapping and nest box methods besides pitfall traps, failed to record any specimens of the cotton mouse, *Peromyscus gossypinus*, a common species in the Dismal Swamp during the surveys of the 1895-1898 period. The cotton mouse seems to have disappeared from the Swamp; none has been taken since the specimens collected near Corinth Chapel Road in Suffolk by D. Hayne and L. Dice in the 1930s (Dice, 1940).

The results of the field studies conducted in the Dismal Swamp during the 1980's indicate that the Dismal Swamp southeastern shrew (*S. l. fisheri*) is fairly widespread but seems to be restricted to the historic Dismal Swamp (Figure 1). In the upland habitats of the southeastern Virginia region, the smaller *S. l. longirostris* sometimes is common. Because the continued drying of the Dismal Swamp could permit the invasion of the upland subspecies into the Dismal Swamp, the USFWS considered introgression and genetic swamping to be substantial threats, and therefore listed *S. l. fisheri* as federally "threatened" (Federal Register, 26 September 1986). No critical habitat was designated, because the main threat lies in the loss of the taxon from genetic swamping. The Dismal Swamp southern bog lemming also was found in a range of early successional habitats over an area of at least 1,000 km<sup>2</sup>. Because a similar threat of interbreeding did not exist with *S. c. helaleutes* (the nearest populations are in the mountains of western Virginia, perhaps 400 km away), southern bog lemmings were not considered to be in need of the protection of federal law. The distribution of the southern bog lemming in the region is approximately the same as shown in Figure 1. At present, *Sorex longirostris fisheri* has the protection of federal and state law with its status as "threatened" but the southern bog lemming, formerly a species of "special concern" in Virginia, has no legal status in the most recent listing of Virginia mammals, because its populations are widespread in the Dismal Swamp region and seemingly secure.

The genus *Blarina* continues to baffle. The more than 200 shrews collected to date in the region show no clear patterns of sorting themselves into small and large ones, as would be predicted by the sizes of *Blarina carolinensis*, which ranges from 6-8 g in the region, and the large *B. [brevicauda] telmalestes*, specimens of which can weigh up to 23 g. The smaller shrews are more or less restricted to grasslands and other openings of early successional habitat, and the larger shrews tend to be found in shrubby or forested locations, suggesting an ecological separation of *Blarina* species. There is a need for a comprehensive systematic and ecological study of the *Blarina* in the vicinity of the Dismal Swamp.

The disappearance of the cotton mouse is puzzling because it was among the most common small mammals collected during the first decade of study in the Dismal Swamp. *Peromyscus gossypinus*, often the most common woodland mouse in the forests of the Carolinas and Georgia, is at the northern edge of its distribution

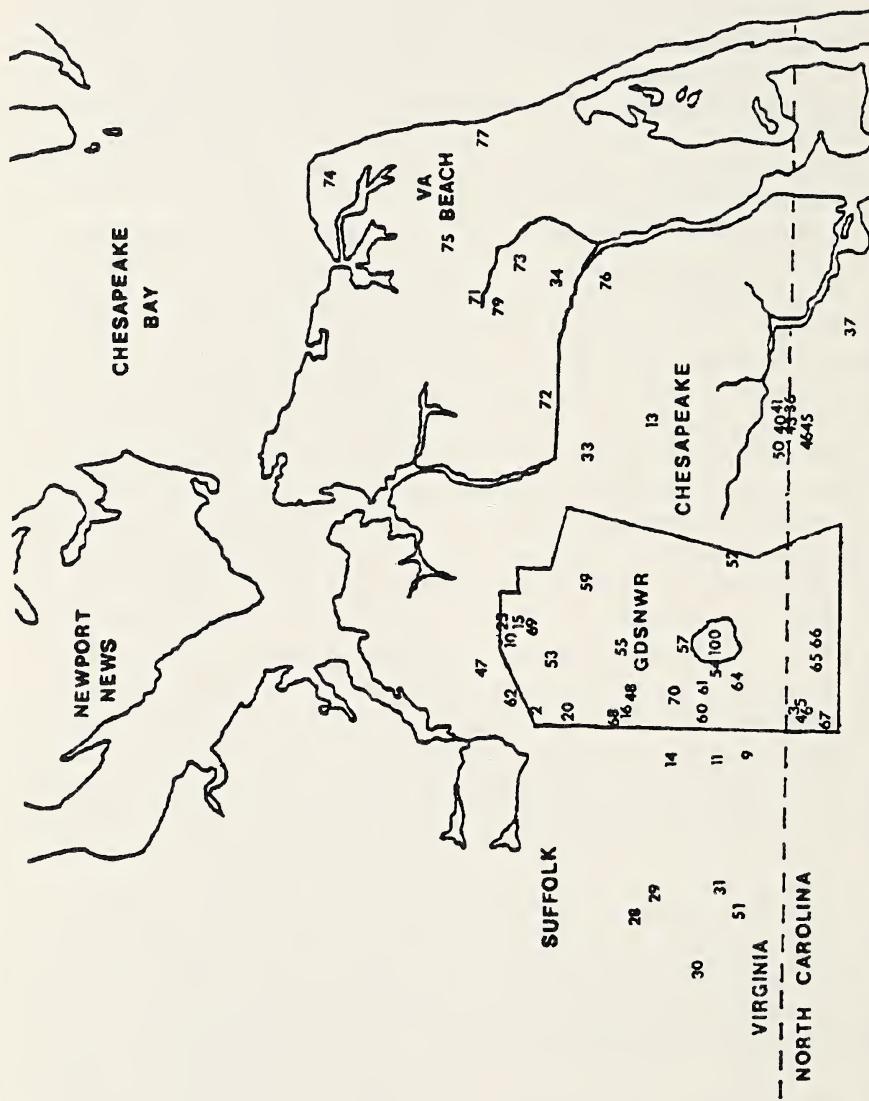


FIGURE 1. Map of southeastern Virginia and adjacent North Carolina showing the locations of capture (represented by the numbers) of the threatened Dismal Swamp southeastern shrew, *Sorex longirostris fisheri*.

in southern Virginia, which may be a contributing factor to its disappearance from the Dismal Swamp forests. Pockets of cotton mice persist along river bottoms of the Nottoway and Blackwater Rivers and cotton mice have been taken 12 miles downstream from Richmond at Presquile National Wildlife Refuge (near Hopewell) on the James River (Pagels, 1976). It would be speculation to suggest that the disappearance of the cotton mouse is due to qualitative changes in the habitats of the Dismal Swamp, but the general drying of the Dismal Swamp, and the related vegetational changes, could have contributed to its demise there. The fact that Virginia populations of *P. gossypinus* persist only in riparian habitat suggests a strong need of moisture or high humidity conditions, at least when coexisting with *P. leucopus*. The populations of *Peromyscus leucopus*, white-footed mouse, and *Ochrotomys nuttalli*, golden mouse, appear to be as common today as 100 years ago (Rose et al., 1990).

The Dismal Swamp has been important as the home for a disjunct population of black bears (*Ursus americanus*). Other bear populations were extirpated in the coastal plain and piedmont regions by the 1830's, but because access by road or boat was so difficult in the Dismal Swamp the bears could not be hunted to extinction there as they were elsewhere. Today the Dismal Swamp black bear population numbers about 300; a few are shot or hit by cars each year on the borders of the GDSNWR, and occasionally individuals from this population migrate widely, even into the heart of Portsmouth (D. Schwab, pers. comm.). The Dismal Swamp, and particularly the GDSNWR, also harbors populations of bobcats (*Lynx rufus*) and river otters (*Lutra canadensis*), 2 furbearers formerly heavily hunted and trapped for their pelts.

#### PROTECTION OF THE MAMMALS

The Dismal Swamp southeastern shrew is a federally protected threatened mammal, but *Synaptomys cooperi helaletes*, formerly a species of special concern in Virginia, seems secure after further studies in the early 1980s. Additional information on the status and distribution of these taxa continues to be collected. Specific studies are needed to measure the extent of introgression by *Sorex longirostris fisheri* populations by the upland *S. l. longirostris*, but these studies are exceedingly difficult to conduct because of the virtual impossibility of catching these animals alive. Clearly, karyological and DNA studies would yield the kinds of information needed to determine the real extent of the threat to Dismal Swamp shrews (*Sorex* and *Blarina*) by introgression from upland conspecifics or congeners.

For the larger mammals, the GDSNWR provides a refuge and sanctuary of sorts, where although the white-tailed deer are hunted, there is no hunting of black bears and no trapping of bobcats, river otters, or the beaver populations that are becoming reestablished there. Because large mammals require large areas to sustain their populations, with continued losses the GDSNWR and other public lands will be the remaining strongholds of these populations. However, small patches of Dismal Swamp forest that are not contiguous with the GDWNWR could continue to be important to the small mammals.

The continued loss of Dismal Swamp forest habitat will have progressive detrimental effects on the endemic mammals. As the area of Dismal Swamp habitat shrinks through a combination of factors, including ditching, fire suppression,

biological succession, fragmentation and conversion of land to agriculture or other uses, the mammals are faced with loss of the habitat conditions in which some of them diverged from the upland populations. Thus, the genetic integrity of some taxa, especially the southeastern shrew, is threatened as the separation, whether ecological or distributional, erodes between upland and Dismal Swamp taxa as the Swamp habitat is lost or fragmented.

#### STEPS LEADING TO THE PROTECTION/PRESERVATION OF DISMAL SWAMP HABITAT

State and federal agencies are striving to secure large tracts of Dismal Swamp habitat, and to manage these lands so that the distinctive nature of the Dismal Swamp can be retained. For example, the Virginia Natural Heritage Program recently secured over 500 ha of swamplands along the Northwest River, adjacent to a large tract of swampland already in Northwest River Park. The GDSNWR has been growing by acquisitions through gifts and purchases, and as of 1991 has an area of more than 47,000 contiguous ha. In an effort to restore a more swamp-like nature, the GDSNWR staff has installed water control structures on many of the canals, with the goal of retaining water in some sections of the Refuge (Swamp). Lengthening the flooding period for a few weeks longer than at present could have the effect of eliminating much of the red maple, and this alone likely would move those sections of the Swamp closer to what they once were. Furthermore, the GDSNWR staff has gained more control (from the US Army Corps of Engineers) over the flow of water from Lake Drummond into the Dismal Swamp Canal, and this too increases the potential for holding more water in Lake Drummond and ultimately of increasing the swamp-like nature of a large area nearby. The management plan for the GDSNWR, implemented in the late 1980s, calls for increasing vegetational diversity by the use of fires and clearcutting of small plots. These actions also are seen as benefitting Dismal Swamp mammals.

Most of the The Dismal Swamp clearly has fallen within the definition of "wetlands" as outlined by the agencies in charge of jurisdictional wetlands. In the summer of 1991 a new definition of wetland was proposed for review through autumn 1991. If this new definition is adopted, much of the land area that has been classified as wetlands in southeastern Virginia would be reclassified. Some people have estimated that as much as 80% of the Dismal Swamp would lose its wetlands classification if the most extreme definition is adopted. Such a change would have devastating effects on those species of mammals that either have evolved in association with the Dismal Swamp or have relied on the isolation afforded by large sections of impenetrable swamplands for their survival in the past. Thus, although large sections of privately owned swamplands are being purchased and preserved by state or federal agencies, much of the Dismal Swamp is currently threatened by greatly increased recent urban development in Virginia Beach, Chesapeake, and Suffolk, and an even greater threat looms with the possible change in the definition of wetlands.

#### FUTURE OUTLOOK FOR THE ENDEMIC SPECIES OF DISMAL SWAMP SMALL MAMMALS

Despite the prospects for continued loss and fragmentation of the Dismal Swamp ecosystem, there are some reasons for optimism that the 3 taxa of small

mammals will survive. As small mammals, southern bog lemmings and Dismal Swamp southeastern and short-tailed shrews can maintain modest population densities even on small tracts, a statement that cannot be made for medium-sized predators or larger mammals of almost any (feeding) type. Also, as small mammals they have large litters and have the potential to recover after their populations are seriously reduced by some external force (such as fire or the reduction of area of habitat because of prolonged flooding). All 3 species have the potential to produce 8-18 young during the one breeding season in which an individual might survive to breed. Furthermore, some current land-use practices in the region, especially forestry practices, often create large tracts of prime habitat for these 3 small mammals. After the land is cleared of trees, the stumps and debris are pushed into windrows and trees are planted between the windrows. After the grasses appear this habitat is quickly used by all 3 species of small mammals. All 3 species are good colonizers and readily find, occupy, and sometimes reach high densities in early successional stages of forest regeneration. Among the habitat types in the region, early successional stages of forest regeneration support the highest densities of all 3 species of small mammals. Thus, as long as substantial amounts of grasses endure (8-10 years), southern bog lemmings will persist, as will modest populations of the 2 shrew species. Once the grasses disappear, so do the southern bog lemmings. However, older forest habitat seems to support low densities of both species of shrew, perhaps 5 individuals/ha (Rose et al., 1990). Thus, shrew densities drop by 50- 80% from their highest levels, but they do persist in the maturing forests. The major threats to these small mammals lie not in the size of the habitat patches so much as in the drying of their habitats and, for some, the threat of interbreeding with upland populations.

By contrast, large mammals require large tracts of land, such as are afforded by the GDSNWR to populations of black bears and otters. If regional development continues at the present pace or is hastened by changes in the definition of wetlands, large mammals in the region may survive only in the Refuge, as the black bears have done for the past 150 years for other reasons.

In conclusion, the Dismal Swamp seems to have served as a refugium for some taxa of mammals, isolating some populations of small mammals and allowing them to diverge and even become morphologically distinct during the past 3,000 to 5,000 years. Thus, some taxa of small mammals seem to have evolved in association with the development of the Dismal Swamp, a forested swampland with long winter hydroperiod that has resisted 2-3 centuries of efforts to develop but now faces increased threats.

#### LITERATURE CITED

- Dice, L. R. 1940. Relationships between the wood-mouse and cotton-mouse in eastern Virginia. *Journal of Mammalogy* 21:14-23.
- Frost, C. C., and L. J. Musselman. 1987. History and vegetation of the Blackwater Ecologic Preserve. *Castanea* 52:16-46.
- Handley, C. O., Jr. 1979. Mammals of the Dismal Swamp: A historical account, pp. 297-357 in P. W. Kirk, Jr. ed. *The Great Dismal Swamp*, University Press of Virginia, Charlottesville.

- Kearney, T. H. 1901. Report on a botanical survey of the Dismal Swamp region. Contributions of the U. S. National Herbarium 5:321-550.
- Merriam, C. H. 1895a. Revision of the shrews of the American genera *Blarina* and *Notiosorex*. North American Fauna Series 10:5-34.
- \_\_\_\_\_. 1895b. Synopsis of American shrews of the genus *Sorex*. North American Fauna Series 10:57-100.
- \_\_\_\_\_. 1896. Revision of the lemmings of the genus *Synaptomys*, with descriptions of new species. Proceedings Biological Society of Washington 10:55-64.
- \_\_\_\_\_. 1897. Description of a new muskrat from the Great Dismal Swamp, Virginia. Proceedings Biological Society of Washington 11:143.
- Murray, J. J. 1965. The Great Dismal Swamp. pp. 249-257 in O. S. Pettingill, Jr. ed. The bird watcher's America. 1974. Apollo ed., Thomas Y. Crowell Co., New York.
- Oaks, R. Q., Jr., and D. R. Whitehead. 1979. Geologic setting and origin of Dismal Swamp, southeastern Virginia and northeastern North Carolina. pp. 1-24 in P. W. Kirk, Jr., ed. The Great Dismal Swamp, University Press of Virginia, Charlottesville.
- Pagels, J. F. 1976. The mammals of Presquile, Chesterfield County, Virginia. Virginia Journal of Science 27:20-23.
- Rhoads, S. N., and R. T. Young. 1897. Notes on a collection of small mammals from northeastern North Carolina. Proceedings of the Academy of Natural Sciences, Philadelphia (1897):303-312.
- Rose, R. K. 1981a. *Synaptomys* not extinct in the Dismal Swamp. Journal of Mammalogy 62:844-845.
- \_\_\_\_\_. 1981b. Small mammals in openings in Virginia's Dismal Swamp. Brimleyana 6:45-50
- \_\_\_\_\_, R. K. Everton, J. F. Stankovich, and J. W. Walke. 1990. Small mammals in the Great Dismal Swamp of Virginia and North Carolina. Brimleyana 16:87-101.
- Whitehead, D. R., and R. Q. Oaks, Jr. 1979. Developmental history of the Dismal Swamp. pp. 25-43 in P. W. Kirk, Jr. ed. The Great Dismal Swamp, University Press of Virginia, Charlottesville.

## Free-Ranging Domestic Cat Predation on Native Vertebrates in Rural and Urban Virginia

Joseph C. Mitchell, Department of Biology,

University of Richmond, Richmond, Virginia 23173  
and

Ruth A. Beck, Department of Biology,

College of William and Mary, Williamsburg, Virginia 23185

### ABSTRACT

Introduced as early as 1614 and imported into the United States in the early 1800s to control rodents in eastern cities, domestic cats (*Felis catus*) have become major predators of native vertebrates. We studied the diversity and seasonality of free-ranging domestic cat predation on native Virginia vertebrates in a rural environment July 1989 - November 1990 and in an urban environment January - November 1990. A total of 27 species (8 bird, 2 amphibian, 9 reptile, 8 mammal) was captured by a single rural cat. One was a mammal of special concern (star-nosed mole). Four urban cats captured 21 species (6 bird, 7 reptile, 8 mammal). The mean number of individuals caught per cat Jan.- Nov. 1990 was 26 in the urban area and 83 in the rural area. Extrapolation of the number of native vertebrates killed annually by the estimated 1,048,704 free-ranging cats reveals a large, but unrecognized and understudied, negative impact on the biota of Virginia.

**Key Words:** domestic cats, birds, mammals, amphibians, reptiles, predation, conservation

### INTRODUCTION

Domestic cats are not native to North America. They first arrived in the company of British colonists as early as 1614 and were imported in the early 1800s to control rodents in eastern cities (George, 1974; Lloyd, 1986). Cats migrated from Europe to other continents and island chains with human travelers and are now important predators worldwide. Unfortunately, the introduction of domestic cats into ecosystems in which they previously did not occur has had a devastating effect on many native species, in some cases causing species extinctions (Atkinson, 1989).

The introduction of an alien species into an ecosystem usually causes a range of negative effects on populations of native species. These include predation, hybridization, competition for food or nest sites, introduction of diseases, parasitism, and indirect environmental chain reactions (Diamond and Case, 1986; Atkinson, 1989). Although several studies have demonstrated that cats are effective predators (e.g., George, 1974; Churcher and Lawton, 1987, 1989), their impact as competitors, disease vectors, and roles in environmental chain reactions have not been addressed.

To our knowledge cats have not been shown to be the primary cause of the loss of native species on mainland continents, although there is documentation of predation on extremely large numbers of native vertebrates (Llewellyn and Uhler, 1952; George, 1974; Liberg, 1984; Churcher and Lawton, 1987; Coleman and

Temple, 1989). Cats have, however, caused the extinction of native birds on at least one island (Ascension Island, Olson, 1977).

Recognition of the extent of predation by free-ranging domestic cats on native animals by the general public is not widespread. This paper, based on our observations in rural and urban Virginia, demonstrates the effect of free-ranging cats on native vertebrates inhabiting the Commonwealth. Our objectives are to quantify the diversity of species killed by these predators in each landscape type and to examine seasonal variation in prey taken. We extrapolate the quantitative results of this study to the estimated number of free-ranging cats in Virginia in order to obtain an estimate of the number of native vertebrates killed annually by this introduced species.

#### MATERIALS AND METHODS

We identified to the species level vertebrate prey killed by free-ranging domestic cats in 2 locations in Virginia. Observations in a rural landscape were made at a 25 acre New Kent County homesite July 1989 through November 1990. The site is located near an old, approximately 21 acre millpond, and is nearly surrounded by mixed hardwood forest with a variably sparse to dense understory of holly and rhododendron. Approximately half of the yard is landscaped with scattered shrubs and half is a vegetable garden. There are no other houses within sight of the study location.

Observations in an urban landscape were made in a western Henrico County subdivision January through November 1990. The area was formerly deciduous forest that had been used for farmland, abandoned, and allowed to succeed to mature oak-dominated woodlands. Suburban style homes were constructed in the 1950s, although several widely scattered older homes were present before that time. The homesite in which the urban observations were made contains several hardwood trees and natural landscaping. An adjacent, abandoned plot contains a former homesite with 3 large shade trees residing in a pine - mixed hardwood association.

We independently accumulated data on species killed by domestic cats. Observations at the rural site were made on a single free-ranging siamese cat, whereas observations at the urban site were made on 4 free-ranging long-haired cats. Free-ranging cats are those that have access to and utilize food supplied by humans, and are not entirely confined to the indoors. Feral cats, those that avoid humans and domestic food sources and reproduce in the wild (Berkeley, 1982), were not included in this study.

Prey killed and brought to the homesites by these cats were identified to species where possible and the dates noted. Systematic searches of the area were conducted on a routine basis, usually daily. These data do not include prey killed and completely consumed or prey that were killed and left elsewhere. Thus, the numbers presented in this study are minimal estimates. Nonnative vertebrate prey, such as house sparrows and house mice, are not included in the comparisons.

Data are tabulated on a monthly basis for comparison between landscape types. Statistical differences between samples were evaluated with a chi-square test, and *a priori* significance was set at  $P \leq 0.05$ .

## RESULTS

Prey killed by the 5 domestic cats represent 5 of the 7 major groups of vertebrates found in Virginia (Table 1). No fish or salamanders were recorded in this study. During the period of overlap between the 2 studies, January - November 1990, the rural cat killed 8 species of birds compared to the 6 positively identified species killed by the 4 urban cats. Total numbers for each site per cat were 25 rural and 3 urban (Table 1). The difference is significant ( $X^2 = 17.3$ ,  $P < 0.001$ ).

A greater number and more species of small mammals were killed by the urban cats than the rural cat (Table 1). The average number killed per urban cat (18.8) is not significantly different ( $X^2 = 1.2$ ,  $P > 0.25$ ) from that killed by the rural cat (26).

Only the rural cat caught, killed, and partially consumed frogs (Table 1). In all cases only the posterior portion of the trunk and the hindlimbs were consumed. Frogs were reported a domestic cat prey in only 1 other North American study (Korschgen, 1957).

Significantly more lizards were killed by the rural cat than the 4 urban cats (Table 1) ( $X^2 = 4.5$ ,  $P < 0.05$ ). The number of snake taxa and number of individual snakes killed were similar between sites (Table 1). The difference is nonsignificant ( $X^2 = 0.8$ ,  $P > 0.75$ ). The difference between the average per cat (9.0 rural, urban 2.8) is marginally nonsignificant ( $X^2 = 3.3$ ,  $P = 0.075$ ).

The total average number of native vertebrates killed by the urban cats (26) during January - November 1990 was significantly fewer than the 83 killed by the single rural cat ( $X^2 = 29.8$ ,  $P \ll 0.001$ ).

The rural component of this study also included data from July through December 1989. During this period an additional 4 shrews, 16 rodents, 7 birds, 7 lizards, and 4 snakes were killed. Species not included in Table 1 are the southeastern shrew and northern ringnecked snake. One individual of a species of special concern (star-nosed mole, Handley, 1991) was taken on 9 May 1989 by the rural cat.

Seasonal variation in prey taken was pronounced only at the rural site (Figure 1 and 2). Birds were taken more frequently during December 1989 through April 1990, whereas reptiles dominated the number of prey taken May through August 1990 (Table 2). Small mammals were taken in small but similar numbers during the periods of August - November 1989 and March - November 1990. Rabbits and frogs were taken only in spring and summer. Although small mammals numerically dominated the prey taken by the urban cats, there are no obvious seasonal trends within this group or any of the other major taxonomic groups (Figure 2, Table 2).

Introduced vertebrates were also killed by the 5 cats. The rural cat killed 3 house mice in October 1989, and 1 in February, 2 in September, and 1 in October 1990. The urban cats killed 1 house sparrow in each of the months of June, July, and October 1990.

## DISCUSSION

Why are cats broadly successful alien predators when most introductions of nonnative species result in limited local and regional effects? A successful invading species possesses a suite of characteristic traits, including vagility, broad diet, short generation time, high genetic variability, gregariousness, association with

TABLE 1. Vertebrates captured by free-ranging domestic cats in rural and urban Virginia January - November 1990.

Species	Rural (1 cat)	Urban (4 cats)
<b>Birds</b>		
Northern Cardinal	2	3
Gray Catbird	0	1
Carolina Chickadee	2	0
American Goldfinch	7	2
Dark-eyed Junco	3	0
Ruby-crowned Kinglet	1	0
White-throated Sparrow	5	0
Wood Thrush	0	1
Tufted Titmouse	2	2
Carolina Wren	3	1
Unidentified	0	2
Total	25	12
<b>Mammals</b>		
Least Shrew	1	0
Northern Short-tailed Shrew	0	35
Eastern Mole	2	2
Eastern Cottontail	2	0
Eastern Chipmunk	0	4
Gray Squirrel	1	4
Southern Flying Squirrel	0	4
White-footed Mouse	15	3
Meadow Vole	3	6
Woodland Vole	2	17
Total	26	75
<b>Frogs</b>		
Green Frog	3	0
Fowler's Toad	4	0
Total	7	0
<b>Lizards</b>		
Eastern Fence Lizard	7	0
Five-lined Skink	5	1
Broadhead Skink	4	0
Ground Skink	0	5
Total	16	6
<b>Snakes</b>		
Eastern Worm Snake	4	2
Black Racer	1	0
Northern Ringneck Snake	0	2
Black Rat Snake	2	0
Rough Green Snake	1	4
Redbelly Snake	0	1
Eastern Ribbon Snake	1	0
Smooth Earth Snake	0	2
Total	9	11
Grand Total	83	104
Average per cat	83	26

TABLE 2. Seasonal variation in native vertebrates killed by rural and urban free-ranging domestic cats in Virginia July 1989 through November 1990. Abbreviations: Sh - shrews and moles, Ro - rodents, Lag - lagomorphs, Bd = birds, Liz - lizards, Sn - Snakes, and Fg - frogs. Note that the urban database contains no lagomorphs or frogs.

Month	Sh	Ro	Lag	Bd	Liz	Sn	Fr
RURAL SITE							
1989							
July							
August	2	5				4	3
September	2	4				3	
October		3					
November		4					
December					7		
1990							
January					4		
February					7		
March		4			4		
April	1	2	1	8	2	4	1
May		5	1		5	4	1
June		2		1	4	1	4
July	1				3	2	
August		1		1	1	2	
September	1	3			1	1	1
October		3					
November		2					
URBAN SITE							
1990							
January						3	1
February	6	11					1
March		2		3			
April	2	3					2
May	2	2			1	2	
June	6	4		3	2	2	
July	14	2		3		1	
August	3	2		1			
September		1				1	
October	4	7		2			1
November	1	5					

*Homo sapiens*, and ability to function in a wide range of physical conditions (Ehrlich, 1989). Anyone familiar with domestic cats will associate these characters with them.

Because our observations are based on domestic cats that brought prey to home sites where they could be counted, the logical assumption was made that all of the prey killed by the cats in this study were unknown to us. George (1974) estimated that about half of the prey killed by his farm cats were counted. The rest were eaten or left elsewhere and scavenged by other animals. On one occasion, after this study

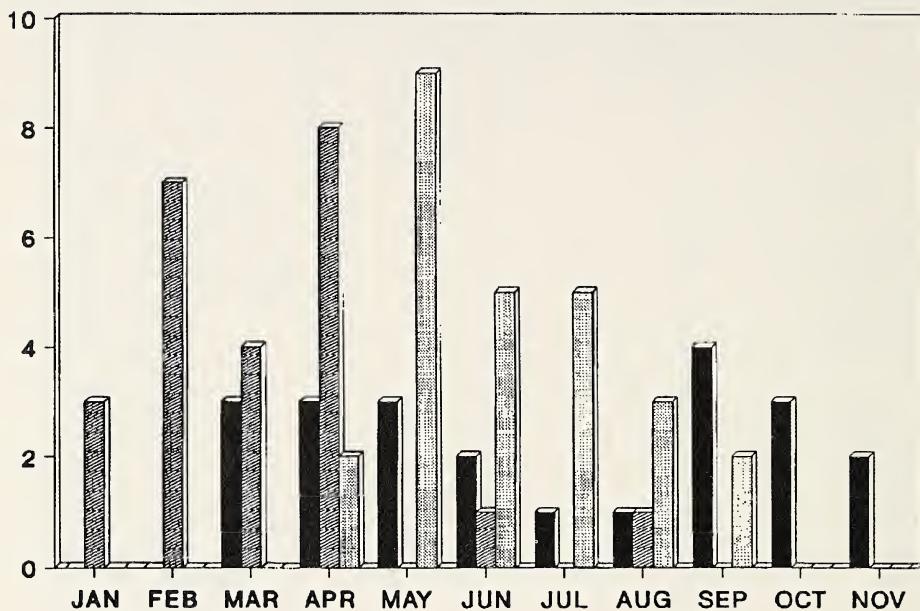


FIGURE 1. Seasonal variation in domestic cat predation on 3 groups of vertebrates in rural Virginia. Solid bars represent mammals, oblique lines represent birds, and stippling represents reptiles (lizards and snakes).

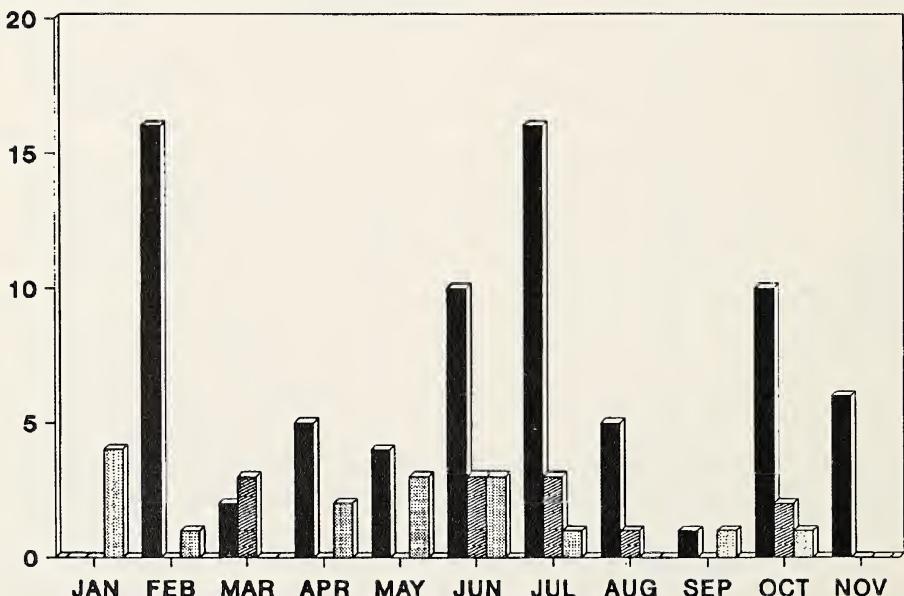


FIGURE 2. Seasonal variation in domestic cat predation on 3 groups of native vertebrates in urban Virginia. Legend for prey types as in Figure 1.

TABLE 3. Ranks of native vertebrates killed by free-ranging domestic cats in North America. Sources: 1 - Hubbs, 1951; 2 - Parmalee, 1953; 3 - Korschgen, 1957; 4 - Warner, 1985; 5 - George, 1974; 6 - Errington, 1936; 7 - Bradt, 1949; 8 - Toner, 1956; 9 - Eberhard, 1954; 10 - Llewellyn and Uhler, 1952; 11 - this study, 1990 data only.

Location	Shrews	Rodents	Lagomorphs	Birds	Reptiles	Other	Source
California	--	1	3	2	--	--	1
Texas	--	1	3.5	3.5	2	--	2
Missouri	5	1	3	4	6	2	3
Illinois	--	1	3	2	--	--	4
Illinois	4	1	2	3?	--	--	5
Wisconsin	5	1	4	2	--	3	6
Michigan	3	1	4	2	--	--	7
Ontario	2	1	--	3	--	--	8
Pennsylvania	4	1	2	3	--	--	9
Maryland	5	1	4	3	--	3	10
Virginia							
Rural	6	1	5	2.5	2.5	4	11
Urban	2	1	--	3	4	--	11

was terminated, one of us (JCM) witnessed a cat kill and entirely consume a chipmunk away from the homesite. Thus, the number of individuals and the diversity of species we tabulated in this study are less than those actually killed.

Of the prey observed in this study none was larger than about half the size of the cat predator. The rural cat was observed stalking gray fox, raccoon, and Virginia opossum but none was attacked or killed. Large snakes are probably avoided as 2 of the urban cats were extremely wary of a 1.3 meter black rat snake (*Elaphe obsoleta*) which struck at one of them. They remained so for at least 30 min. after the snake was removed from the homesite. Large snakes and mammals have not been reported as cat prey in the literature.

Comparisons of the numerical rank order of prey types killed by domestic cats in North America (Table 3) shows that rodents are, without exception, the primary prey taxon taken. All other groups have ranked second at least once.

Reptiles ranked high only in a study conducted in Texas (Parmalee, 1953) and in the rural site in this study. Although snakes were consumed, the majority of the prey in both these studies were lizards. Species listed under "other" include insects, other invertebrates, and frogs (Errington, 1936; Llewellyn and Uhler, 1952; Korschgen, 1957; this study).

Although birds were not the primary prey type killed in any of the published studies, they always ranked second or third behind rodents (Table 3). In most cases the species listed include those that nest on or near the ground or those that feed on the ground. Wilcove (1985) experimentally demonstrated that songbirds nesting on the ground or in low vegetation were subjected to very high levels of predation. He determined that domestic cats, along with raccoons, opossums, skunks, and blue jays, were the primary predators of migratory songbirds in isolated forested tracts in suburban Maryland.

Seasonal variation in prey taken by domestic cats in this study differed between sites. Such variation derives from (1) individual differences in cat behavior, (2) availability of prey types due to habitat and seasonal differences, and (3) variation in susceptibility of prey among taxa, age, and seasons. The rural cat, for instance, preyed almost exclusively on songbirds during the winter when they were using artificially stocked feeders. The birds were presumably more susceptible to predation at that time. However, the rural cat switched from 1 prey resource to another at will, as evidenced from the results in Table 2. The lack of seasonal variation in the urban site may have been partially due to individual variation in cat behavior. Two of the 4 cats demonstrated frequent prey capture success, a third was variable, and a fourth (a fixed male) was comparatively ineffective.

Using our results, we extrapolated the impact of free-ranging cats on native vertebrates in Virginia. We estimated the number of cats by dividing the 1990 human census estimate of 6,187,358 (Southeast Regional Census Bureau, Charlotte, NC, pers. comm.) by 5.9, the ratio of one cat (excluding feral cats) to every 5.9 humans (American Humane Association, 1972). The resulting 1,048,704 cats multiplied by the average number of songbirds killed by urban cats (3) and the total number killed by the rural cat (25) from January to November 1990 yields a range of 3,146,112 to 26,217,600 songbirds killed statewide. This number is certainly inaccurate to some degree, although the estimates are impressive. Similar computations yield 27,266,304 - 78,528,800 for small mammals and 2,883,936 - 9,438,336 for reptiles. Although we would concur that domestic cats may play a positive role in controlling some rodent populations in the absence of natural predators (e.g., large snakes, birds of prey), we point out that these introduced predators may play a significant role in the decline of our native wildlife. This is especially true when one considers that there are approximately 60 million cats in North America (Springston, 1991). Future conservation efforts on behalf of native vertebrates must include some measure of protection from free-ranging domestic cats.

We recognize the limitations of extrapolation to large areas from relatively small data sets such as ours. A primary purpose in presenting these data is to stimulate more careful and detailed studies that can reveal truer estimates of the impact of this introduced species. We strongly suggest that several well-placed, simultaneous studies in rural and urban Virginia be conducted using the techniques of Churcher and Lawton (1987). A more accurate ratio of cats to humans in Virginia is needed in order to provide a better extrapolation to the entire domestic cat population. We urge everyone to use this information to educate people of all ages to the role cats may play in the decline of Virginia's native wildlife. If Virginia's wildlife agency is convinced that the impact of cat predation on native species is important, as we think they should be, then their help with public awareness may lead to constraints in the growth of cat numbers and controls on their predatory behavior.

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We are grateful to Joshua, Justin, Tanya, and Wendy Mitchell for their assistance with keeping score on the vertebrates killed by the urban cats. Michael and Sherwin Beck assisted in the rural study site. Betty Tobias, University of Richmond Science librarian, helped to secure several important references. JCM contributed the urban data and wrote the paper; RAB contributed the rural data.

## LITERATURE CITED

- Anonymous. 1972. Animal Control Survey. American Humane Society, 32 pp.
- Atkinson, I. 1989. Introduced animals and extinctions. Pp. 54-75 In D. Western and M.C. Pearl eds. Conservation for the Twenty-first Century. Oxford University Press, New York.
- Berkeley, E.P. 1982. Maverick Cats: Encounters with Feral Cats. Walker Publishing Company. New York, 142 pp.
- Bradt, G.W. 1949. Farm cat as a predator. Michigan Conservation 18:23-25.
- Churcher, P.B. and J.H. Lawton. 1987. Predation by domestic cats in an English village. Journal of Zoology, London 212:439-455.
- \_\_\_\_\_, and \_\_\_\_\_. 1989. Beware of well-fed felines. Natural History Magazine. 95:40-46.
- Coleman, J.S. and S.A. Temple. 1989. Effects of free-ranging cats on wildlife: A progress report. Fourth Eastern Wildlife Damage Control Conference, Madison, Wisconsin, pp.9-12.
- Conant, R. and J.T. Collins. 1991. A Field Guide to the Reptiles and Amphibians of Eastern North America. Houghton Mifflin Publishing Company, Boston. 450 pp.
- Diamond, J. and T.J. Case. 1986. Overview: Introductions, extinctions, extirpations, and invasions. Pp. 65-79 In J. Diamond and T.J. Case eds. Community Ecology, Harper and Row Publishers, New York.
- Eberhard, T. 1954. Food habits of Pennsylvania house cats. Journal of Wildlife Management 18:284-286.
- Ehrlich, P.R. 1989. Attributes of invaders and the invading processes: vertebrates. Pp. 315-328 In J.A. Drake et al. eds. Biological Invasions: a Global Perspective. John Wiley and Sons Ltd., New York.
- \_\_\_\_\_, D.S. Dobkin, and D. Wheye. 1988. The Birder's Handbook. Simon and Schuster Inc., New York, 785 pp.
- Errington, P.L. 1936. Notes on food habits of southern Wisconsin house cats. Journal of Mammalogy 17:64-65.
- George, W.G. 1974. Domestic cats as predators and factors in winter shortages of raptor prey. Wilson Bulletin 86:384-396.
- Handley, C.O., Jr. 1991. Mammals. Pp. 539-562 In K. Terwilliger (Coordinator) Virginia's Endangered Species, McDonald and Woodward Publishing Company, Blacksburg, Virginia.
- Hubbs, E.L. 1951. Food habits of feral house cats in Sacramento Valley. California Fish and Game 37:177-189.
- Korschgen, L.L. 1957. Food habits of coyotes, foxes, house cats, and bobcats. Missouri Conservation Commission Bulletin, P-R Series 15:1-64.
- Liberg, O. 1984. Food habits and prey impact by feral and house-based domestic cats in a rural area in southern Sweden. Journal of Mammalogy 65:424-432.
- Llewellyn, L.M. and F.M. Uhler. 1952. Foods of fur animals of the Patuxent Research Refuge, Maryland. American Midland Naturalist 48:193-203.
- Lloyd, A.T. 1986. Pussy cat, pussy cat, where have you been? Natural History Magazine 95:46-53.
- Olson, S.L. 1977. Additional notes on the subfossil bird remains from Ascension Island. Ibis 119:37-43.

- Parmalee, P.W. 1953. Food habits of the feral house cat in east-central Texas. *Journal of Wildlife Management* 19:375-376.
- Springston, R. 1991. Killer cats threatening Va. wildlife. *Richmond News-Leader*. June 13, Section B.
- Toner, G.C. 1956. House cat predation on small mammals. *Journal of Mammalogy* 37:119.
- Warner, R.E. 1985. Demography and movements of free-ranging domestic cats in rural Illinois. *Journal of Wildlife Management* 49:340-346.
- Webster, W.D., J.F. Parnell, and W.C. Biggs, Jr. 1985. *Mammals of the Carolinas, Virginia, and Maryland*. University of North Carolina Press, Chapel Hill, North Carolina.
- Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. *Ecology* 66:1211-1214.

**APPENDIX 1.** Scientific names of species mentioned in the text. Common and scientific names follow Ehrlich et al. (1988) for birds, Webster et al. (1985) for mammals, and Conant and Collins (1991) for amphibians and reptiles.

#### Birds

Northern Cardinal	<i>Cardinalis cardinalis</i>
Gray Catbird	<i>Dumetella carolinensis</i>
Carolina Chickadee	<i>Parus carolinensis</i>
American Goldfinch	<i>Carduelis tristis</i>
Dark-eyed Junco	<i>Junco hyemalis</i>
Ruby-crowned Kinglet	<i>Regulus calendula</i>
House Sparrow	<i>Passer domesticus</i>
White-throated Sparrow	<i>Zonotrichia albicollis</i>
Wood Thrush	<i>Hylocichla mustelina</i>
Tufted Titmouse	<i>Parus bicolor</i>
Carolina Wren	<i>Thryothorus ludovicianus</i>

#### Mammals

Least Shrew	<i>Cryptotis parva</i>
Northern Short-tailed Shrew	<i>Blarina brevicauda</i>
Southeastern Shrew	<i>Sorex longirostris</i>
Eastern Mole	<i>Scalopus aquaticus</i>
Star-nosed Mole	<i>Condylura cristata</i>
Eastern Cottontail	<i>Sylvilagus floridanus</i>
Eastern Chipmunk	<i>Tamias striatus</i>
Gray Squirrel	<i>Sciurus carolinensis</i>
Southern Flying Squirrel	<i>Glaucomys volans</i>
White-footed Mouse	<i>Peromyscus leucopus</i>
House Mouse	<i>Mus musculus</i>
Meadow Vole	<i>Microtus pennsylvanicus</i>
Woodland Vole	<i>Microtus pinetorum</i>

**Frogs**

Green Frog  
Fowler's Toad

*Rana clamitans melanota*  
*Bufo woodhousii fowleri*

**Lizards**

Eastern Fence Lizard  
Five-lined Skink  
Broadhead Skink  
Ground Skink

*Sceloporus undulatus undulatus*  
*Eumeces fasciatus*  
*Eumeces laticeps*  
*Scincella lateralis*

**Snakes**

Eastern Worm Snake  
Black Racer  
Northern Ringneck Snake  
Black Rat Snake  
Rough Green Snake  
Redbelly Snake  
Eastern Ribbon Snake  
Smooth Earth Snake

*Carphophis amoenus amoenus*  
*Coluber constrictor constrictor*  
*Diadophis punctatus edwardsii*  
*Elaphe obsoleta obsoleta*  
*Opheodrys aestivus*  
*Storeria occipitomaculata occipitomaculata*  
*Thamnophis sauritus sauritus*  
*Virginia valeriae valeriae*



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## **NOTES**

## **NOTES**

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**ABSTRACTS OF PAPERS**  
**70th Annual Meeting of the Virginia Academy of Science**  
**May 19-22, 1992, University of Richmond**  
**Richmond, Virginia.**

**Aeronautical and Aerospace Sciences**

CONTROL OF LOW-SPEED TURBULENT FLOW OVER A TWO-DIMENSIONAL REARWARD-FACING RAMP USING ASYMMETRIC JET VORTEX GENERATORS. Pamela K. Askew and Gregory V. Selby, Dept. of Mech. Engrg. and Mechanics, Old Dominion University, Norfolk, VA 23529-0247. An experimental study of the relative effectiveness of asymmetric jet vortex generators in reducing pressure drag on a two-dimensional rearward-facing ramp has been conducted. Several jet orifice configurations were tested in an attempt to determine an optimal jet orifice shape that would significantly improve the pressure recovery over the ramp when compared with the baseline configuration (jets off). For each jet orifice configuration considered, the streamwise pressure distribution over the curved portion of the ramp was measured and used to calculate differences in the pressure drag. Each jet orifice configuration produced a reduction in pressure drag with respect to the baseline configuration.

SMOKE-WIRE FLOW VISUALIZATION OF ROTATING-DISK FLOW. Alan E. Blanchard and Gregory V. Selby, Dept. of Mech. Engrg. and Mechanics, Old Dominion University, Norfolk, VA 23529-0247. Throughout the past thirty years, experimental investigations of rotating-disk flow have been conducted using quantitative techniques such as hot-wire anemometry and qualitative techniques such as surface flow visualization using titanium tetrachloride. Based on these studies, the present physical model of rotating-disk flow transition assumes that flow instabilities manifest themselves as primary crossflow vortices with nucleation sites that are probably dust motes. These primary vortices grow in amplitude with increasing Reynolds number until secondary ring-like vortices encircle each individual primary vortex just inboard of the fully turbulent region. The purpose of the present research was to develop a method of composite imagery applicable to smoke-wire flow visualization data which would allow a detailed examination of the transition process and consequently, further refinement of the flow model.

AN ANALYTICAL INVESTIGATION OF THE NITRIC OXIDE CONTAMINATION LEVELS IN THE TEST FLOW OF THE Langley ARC-HEATED SCRAMJET TEST FACILITY. Karen E. Fischer, NASA Langley Research Center, Hampton, Va. 23665. A finite rate chemical analysis has been made of the flow in the Langley Arc-Heated Scramjet Test Facility (AHSTF) to assess the levels of nitric oxide contamination in the test gas at several test conditions. Nitric oxide is produced when the facility air flow is heated to the high energy levels required to simulate hypersonic flight conditions for free-jet scramjet engine tests. The analysis was performed across the operating range of the AHSTF which includes simulated flight Mach numbers of 5.5, 6, 7, and 8. This paper describes the analysis beginning with heat addition to the flow in the arc-heater, mixing of the heated air with unheated bypass air in a plenum chamber, and flow through the facility nozzles (either Mach 4.7 or 6) to the test section entrance. The nitric oxide levels deduced analytically will be compared to earlier experimental measurements. A knowledge of the nitric oxide levels is essential to determine the effect on ground facility scramjet performance data and the projection of this data to flight conditions.

APPLICATION OF AN OBJECT-ORIENTED SOFTWARE ARCHITECTURE FOR A LASER BASED STRUCTURAL IMAGING SYSTEM. Michael D. Gavaghan, Department of Mechanical Engineering, Virginia Tech, Blacksburg, VA 24061-0238.

This paper presents an evolving object-oriented software architecture that has been developed in support of a laser based structural imaging research project. The structural imaging concept involves superimposing the dynamic response of a structure to excitation onto a mathematical model of the structure's geometry. These measurements are obtained primarily using a scanning laser velocimeter. The software for this project was designed to reduce and isolate hardware dependencies and to promote methodology development through rapid prototyping. This paper describes the stand-alone modules developed to perform as virtual instruments with the flexibility to adapt to changing hardware configurations. Other benefits such as the creation of reusable code are also discussed.

COMPARATIVE STUDY OF UNSTRUCTURED AND LOCALLY STRUCTURED GRIDS FOR COMPLEX GEOMETRIES E. Oktay, J. Newman, O. Baysal, Mechanical and Mechanics Dept. ODU. Norfolk, Va. 23529. With the advances in computer technology and the development of efficient grid generation algorithms, complex configurations requiring large numbers of nodal points may now be approached. The method by which these points are distributed is classified as either unstructured or structured grid generation. To illustrate the advantages and disadvantages of each method, a comparative study utilizing both techniques about a wing-pylon-finned store configuration is presented. The unstructured grid generator is based on the 'advancing front technique' whereas, the structured mesh is comprised of both multiblock and overlapped grids.

APPLICATION OF JET VORTEX GENERATORS TO A BLUNT TRAILING-EDGE AIRFOIL IN LOW-SPEED TURBULENT FLOW. Hamid Sayar and Gregory V. Selby, Dept. of Mech. Engrg. and Mechanics, Old Dominion University, Norfolk, VA 23529-0247. An experimental study has been performed with jet vortex generators to determine their effectiveness in increasing the base pressure of a two-dimensional blunt trailing-edge airfoil in low-speed turbulent flow. A single row of jet orifices was located just upstream of the base of the airfoil model. The level of pressure increase achieved was found to be a function of the jet orientation angle with respect to the free-stream direction, for a given value of jet diameter and speed. Jets oriented 90 deg. from the free-stream direction (angle measured in a horizontal plane) were the most effective.

COMPARATIVE STUDY OF UNSTRUCTURED AND LOCALLY STRUCTURED GRIDS FOR MULTIPLE BODY K.P.Singh, J.Newman, O.Baysal, Mechanical Engg and Mechanics Department, ODU, Norfolk, Va. 23529. A major concern in Computational Fluid Dynamics is the discretization of the physical domain. Discretization methods have been intensely researched and classified as either Unstructured or Structured grid generation. It has been found that unstructured techniques are better suited for complex and multiple component configurations due to the nature of the cells which discretize the domain, and the freedom associated with having no restrictions placed on the directionality. The above pitfalls, however may be overcome by using locally structured grids independently generated about components and then incorporating domain decomposition techniques to establish intergrid connections.

Here, a comparative study of unstructured and locally structured grid generation technique about a multiple body geometry is presented. The 3-D unstructured tetrahedral grids are generated using the advancing front method, and the locally structured grids utilized both multiblock and overlapping techniques for inter-grid communication.

**A STUDY OF ALTITUDE-CONSTRAINED SUPERSONIC TRANSPORT CONCEPTS.**

David C. Tice\* and Glenn L. Martin\*, Lockheed Engineering & Sciences Co., 144 Research Dr., Hampton, VA 23666.

Current U. S. and international research programs of High-Speed Civil Transport (HSCT) -type vehicles indicate that these aircraft will be subjected to intense evaluation of their impact on the environment, specifically in the areas of airport community noise, sonic boom, and atmospheric pollution. This study results from consideration of the latter concern, atmospheric pollution. The possible impact of HSCT emissions in the stratosphere may result in restriction of HSCT cruising altitudes. This is because ozone depletion due to NOx emissions is expected to increase with altitude above the troposphere. The study evaluated the effect of restricting maximum cruise altitude on the mission performance of two supersonic transport concepts across a selection of cruise Mach numbers. Trade-offs in performance were evaluated by parametrically varying both cruise Mach number and maximum allowable cruise altitude for two concepts of differing wing loadings, an arrow wing concept and a trapezoidal wing concept. As the maximum allowable cruise altitude was reduced, the designs were restrained to fly at non-optimum angles of attack and lift-drag ratios. This required an increase in mission fuel, and thus gross weight, to meet the mission range. The sensitivity of aircraft size and performance to maximum cruise altitude restrictions and Mach number are presented for the two wing platforms.

**EVALUATION OF ENGINEERING METHODS FOR HYPERSONIC AERODYNAMICS**

PREDICITONS. Abel Torres, Hypersonic Technology Office, NASA Langley Research Center, 1 Helms Avenue, Hampton, Virginia 23665-5225. This presentation illustrates some aspects of the methodology used in present engineering codes to predict aerodynamic characteristics over arbitrary supersonic/hypersonic configurations. These programs use a combination of simplified methods, all based on impact angle and freestream conditions, to compute pressure distribution over the vehicle's surface in an efficient and timely manner. The ability of the user to use the proper methodology when selecting an impact/shadow method is a vital prerequisite to get a correct solution to the given problem. Examples of the codes evaluated include the originals Mark III Hypersonic Arbitrary Program (HABP), the Aerodynamic Preliminary Analysis System (APAS) program, and the Mark IV Supersonic Hypersonic Arbitrary Program (SHAB). Comparisons of the above codes used by the industry/government are presented along with results of Computational Fluid Dynamics (CFD) calculations and experimental data on representative configurations of current interests including the National Aerospace Plane (NASP). In general, when engineering codes are properly applied, excellent results can be obtained making them an invaluable tool to the design engineer.

**FLOW VISUALIZATION OF TURBULENT SUBSONIC FLOW OVER SWEPT REARWARD-FACING RAMPS.** Lillianne P. Troeger and Gregory V. Selby, Dept. of Mech. Engrg. and Mechanics, Old Dominion University, Norfolk, VA 23529-0247. The present study was an investigation of the effectiveness of several passive and active separation control devices in reducing the separation region associated with turbulent flow over backward-facing swept ramps. The oil-dot flow visualization technique was used to visualize the separated flow region. The passive devices tested were: a) Wheeler wishbone vortex generators, b) conventional vane-type vortex generators, and c) spanwise right circular cylinders. Jet vortex generators were the active technique studied. Ramps with sweep angles of 15, 30, and 45 deg. were tested. All of the devices/techniques could be configured to significantly reduce the three-dimensional separation region.

**Agriculture, Forestry and Aquaculture Science**

A COMPARISON OF THE AFTER-INFECTION ACTIVITY OF THE FUNGICIDES TRIADIMEFON AND MYCLOBUTANIL AGAINST GRAPE BLACK ROT (*GUIGNARDIA BIDWELLII*). Anton Baudoin, Dept. of Plant Pathology, Physiology and Weed Science, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. Black rot, caused by *Guignardia bidwellii*, is one of the most costly fungus diseases of grapes in the eastern United States. The fungicide triadimefon (Bayleton) provides effective control of black rot if applied within a few days after infection. Myclobutanil (Nova), which became registered for grapes in 1989, probably has after-infection activity as well. In order to compare the activity of the two compounds, potted grape plants (cv. 'Catawba') with young leaves were inoculated with a suspension containing 50,000 spores/ml, held in a mist chamber for 20 hours, then placed outdoors (mid-June to early August). Fungicides were applied to runoff 1, 3, 5, and 7 days after inoculation. Symptoms were evaluated after 3 weeks. Plants treated 1 day after inoculation did not develop symptoms. "Arrested" chlorotic and necrotic lesions developed on plants sprayed after 3, 5, and 7 days, but fungus sporulation was absent or greatly reduced. Myclobutanil performed as well as or better than triadimefon in preventing production of sporulating black rot lesions. (Supported by the Virginia Winegrowers Advisory Board.)

ALTERNATIVE CULTURE STRATEGIES FOR EASTERN OYSTER, *CRASSOSTREA VIRGINICA*, IN NORTH CAROLINA. B. Brown, Dept. of Biology, Virginia Commonwealth University, Richmond, VA 23284 and K. Paynter, Dept. of Zoology, University of Maryland, College Park, MD 20742. A pilot study is underway to examine performance of selectively bred and native oyster strains in order to document the effect of diseases upon these strains when cultured in North Carolina. The selectively bred group of Eastern oyster, *Crassostrea virginica*, is derived from native Maryland oysters. Native oyster strains include progeny of specimens from Maryland, Virginia, and North Carolina. Floating trays are being employed as culture containers to expose oysters to the optimum growth medium across several sites selected on the basis of varying salinities (5 - 35 ppt). Hydrological and biological parameters being recorded include temperature, salinity, oyster growth, condition index, and levels of infection with Dermo and MSX. Data from this study will enhance the status of knowledge regarding the physiological effects of diseases upon Chesapeake Bay strains of oysters as well as provide information on the major factors affecting successful cultivation of commercial quantities of American oyster in estuaries of the mid-Atlantic.

RELATIVE PERFORMANCE OF STRIPED BASS X WHITE BASS HYBRID AND STRIPED BASS X YELLOW BASS HYBRID IN A RECIRCULATING AQUACULTURE SYSTEM. Brian Bosworth & George S. Libey. Dept. Fish. & Wildl. Sci., Va. Polytechnic Institute and State Univ., Blacksburg, VA. 24061-0321. The growth, feed conversion, condition factor, and survival of striped bass (*Morone saxatilis*) X white bass (*M. chrysops*) with striped bass X yellow bass (*M. mississippiensis*) hybrids reared in recirculating aquaculture systems were compared. Three replicated systems, each consisting of two circular tanks (800 l), a rotating biological contactor, and a sump were used. One hundred white bass hybrid and yellow bass hybrid fingerlings (mean weight = 91.8 and 61.6 grams respectively) were stocked into separate tanks in each system and fed to satiation twice daily for 120 days. Fish were measured for total length and weight every 30 days. Instantaneous growth rate and feed conversion ratio were superior ( $p < 0.05$ ) in white bass hybrids during the second 30 day period, condition factor was higher ( $p < 0.05$ ) in yellow bass hybrids at the end of the study. Survival (mean = 97.5%) was not significantly different between hybrids. Time X hybrid interactions were significant ( $p < 0.05$ ) for instantaneous growth and feed conversion ratio.

PLASMA NONESTERIFIED FATTY ACID RESPONSE TO EPINEPHRINE CHALLENGES DURING THE ESTROUS CYCLE OF LACTATING COWS. J. A. Brunges, C. N. Richmond\*, J. A. Lee\*, and J. H. Herbein, Dept. of Dairy Science, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061-0315.

Nine cows received intravenous epinephrine ( $1 \mu\text{g}/\text{kg}$  body weight) injections to evaluate nonesterified fatty acid (NEFA) release via lipoprotein lipase into plasma on the day of estrus and again during diestrus (11 days following estrus). Indwelling catheters were placed in a jugular vein and an external abdominal mammary vein to contrast whole-body versus mammary gland responses for 20 minutes before and 70 minutes after injection. Five cows were fed a basal diet (50% forage and 50% concentrate dry matter) that met all nutrient requirements. Four cows were fed a high-energy diet (basal diet supplemented with 3% additional lipid in place of corn grain). Diet, however, did not significantly influence overall concentration of NEFA in plasma between 0 and +30 minutes, during which NEFA peaked and returned to baseline. In contrast, overall peak concentration in mammary vein ( $423 \mu\text{Eq/l}$ ) was higher than in jugular vein ( $326 \mu\text{Eq/l}$ ) in response to epinephrine, suggesting that the lipoprotein lipase reaction in mammary tissue is a major source of NEFA during lactation. Stage of estrous cycle also influenced the NEFA response. Overall peak concentration was higher (433 versus  $350 \mu\text{Eq/l}$ ) on day of estrus than during diestrus, with less time (11.6 versus 13.6 minutes) required to achieve peak concentration on day of estrus. Observed alterations in mammary gland sensitivity to epinephrine during the estrous cycle may be a reflection of cyclical changes in concentrations of estrogen and (or) progesterone in plasma and their influence on lipid metabolism. (Supported in part by a senior scholarship and grant from the Pratt Animal Nutrition Program, College of Agriculture & Life Sciences)

#### REMOVAL SAMPLING OF ADULT CARABIDS FOR ESTIMATING

ABSOLUTE DENSITIES. M. S. Clark & J. M. Luna\*. Dept. of Entomology, VPI & SU, Blacksburg, VA 24061. Absolute density estimates were made for adult carabid beetles in a no-till corn field in Riner, Virginia using a removal sampling method. Six square field arenas ( $5.70 \text{ m}^2$ ) were used to isolate randomly chosen sampling areas. Beetles were removed from these areas with barrier pitfall traps. During three 3-week sampling periods between 5 June and 8 August, 1991, 503 individuals in 21 species were collected. Depending upon the number and sequence of individuals of each species captured, one of two methods was used to estimate absolute densities. A linear regression method was used for abundant species in which the estimate is based on the decline in successive catch numbers over time. The absolute number captured was used for less abundant species. Information pertaining to carabid densities in agroecosystems may be useful in evaluating their role in the biocontrol of agricultural pests.

PRODUCTION OF HYBRID STRIPED BASS IN A SMALL SCALE RECIRCULATING SYSTEM. A. Colizzi, Dept. Ocean., Old Dominion University, Norfolk, Va 23529, & A. J. Frovezzano, Jr., Dept. Ocean., ODU, Norfolk, Va. 23529. The hybrid striped bass, a cross between the striped bass (*Morone saxatilis*) and the white bass (*Morone chrysops*), is a hardy fish with high growth and survival rates. The goal of this experiment was to determine growth of hybrid striped bass in intensive culture.

Fingerling hybrid striped bass previously grown in ponds at Virginia State University were stocked into a closed recirculating system and fed daily with Purina trout chow for four months. Start up numbers and biomass were 395 fish weighing 4498 grams. Heavy mortalities in the early weeks of the experiment were caused by disease. After treatment for disease and stabilization of the population, fewer mortalities were observed. After 124 days of culture, 93 fish weighing an average of 66.9 grams, and a biomass 6221.7 grams were tallied. Average fish weight increased from 11.4 grams to 66.9 grams, or  $0.43\text{g/fish/day}$ , this rate is similar in magnitude to reported growth rates of hybrids grown in pond systems.

EFFECTS OF SALINITY ON SURVIVAL AND GROWTH OF THE CRAYFISH,  
PROCAMBARUS ACUTUS ACUTUS. E. Deaver, Applied Marine Res. Lab., Old Dominion Univ., & A. J. Provenzano, Jr., Department of Oceanography, Old Dominion Univ., Norfolk, VA 23529

Crayfish culture, a significant industry in the United States, is conducted primarily in fresh-water environments. Little is known of the potential for crayfish culture in brackish water. The white river crayfish, Procambarus acutus acutus, is one of the dominant species of crayfish cultured in the United States. To assess the potential for brackish water culture, the white river crayfish was tested for growth and survival in low salinity water. Two sizes of juvenile crayfish were placed into replicate pools in the laboratory at 0, 4 and 8 ppt salinity and grown for 75 days. Animals were measured weekly for growth (carapace length and wet weight) and survival. Crayfish grew fastest and had lowest mortality in the 4 ppt treatment. These experiments suggest that brackish water culture of the white river crayfish is possible.

#### COMPOST ORGANISMS AND THEIR ROLE IN DEGRADING PESTICIDES CONTAINED IN A WASTE-PESTICIDE BIOREACTOR.

David N. Judge and Donald E. Mullins\*, Department of Entomology, and Duane F. Berry, Department of Crop and Soil Environmental Sciences, Virginia Tech, Blacksburg, VA 24061

Naturally occurring compost organisms, such as bacteria, fungi, nematodes, mites, and insects, appeared to have a concerted role in degrading pesticides in bioreactors designed to contain and degrade waste pesticides. Bioreactors at ambient temperature contained a variety of steam-exploded lignocellulosic materials and peat moss. The herbicide atrazine placed into liter bioreactors at approximately 10,000 and 5,000 ppm (ug atrazine/g dry matrix) has decreased to 1079 and 489 ppm over a year. Chloryrifos started at 687 ppm has decreased to 478 ppm in eight months. Organisms noted in bioreactors were gram-positive rod-shaped bacteria, dark-winged fungus gnats, and several species of slime mold, fungi, nematodes, and mites. It appears from preliminary studies that the presence of mites assisted in increasing pesticide disappearance. Atrazine disappearance in 250 mL bioreactors with the presence of mites was significantly greater than similar bioreactors that had only bacterial and fungal growth. Possible reasons of increased pesticide disappearance due to mites include physical turning of the bioreactor matrix, digestion, and defecation.

Use of field surveys and blacklight insect traps for corn earworm, Helicoverpa zea (Boddie), (Lepidoptera: Noctuidae) advisories in eastern Virginia. Michael W. Lachance, Va. Cooperative Extension Service, P. O. Box 849, Tappahannock, Va, 22560, and D. Ames Herbert Jr., Dept. of Entomology, V.P. I. & S. U., Tidewater Agricultural Experiment Station, P. O. Box 7099, Suffolk, Va. 23437. The time of second generation corn earworm (CEW) moth flight is estimated by extensive surveys of field corn acreage in July. The mean abundance of the CEW larval sample supply corn producers with early information about the need for possible rescue treatments in soybeans. In addition, the growth stage of the CEW larvae cues subsequent monitoring activity in soybean acreage. Analysis of July and August CEW catches from a network of blacklight traps show that these devices supplement and improve the advisory information. These traps also document the northward lag in CEW phenology. Complete season data are evaluated as cumulative percent trap catches.

COMPARISONS OF CERTAIN MORPHOLOGICAL CHARACTERS OF FEMALES OF GLOBODERA TABACUM VIRGINIAE AND G. T. SOLANACEARUM. L.I. Miller\*. Dept. of Plant Path., Phys. and Weed Sci., VPI&SU, Blacksburg, VA 24061. Comparisons were made of certain characters of females of type locality isolates of Globodera tabacum virginiae (N1) and G. t. solanacearum (N2) when cultured on horse nettle (P1), Solanum carolinense, and tobacco (P2), Nicotiana tabacum cv. VA 312. P1 and P2 were efficient hosts for N1 and N2. Mean dimensions in  $\mu\text{m}$  of 101 specimens were as follows- stylet cone length (SCL): N1P1 11.9, N1P2 12.0, N2P1 12.6, N2P2 13.0; dorsal gland opening (DGO): N2P2 5.1, N1P2 5.5, N2P1 6.0, N1P1 6.1. Comparisons between the nematode subspecies on P1 and P2 were significantly different ( $P=0.01$ ) for the SCL dimensions, but not for the DGO dimensions. The dimensions on P1 and P2 of SCL for N2 were greater ( $P=0.01$ ) than for N1, but there was no significant influence of P1 or P2 on the dimensions of SCL. The dimensions of DGO on P1 for N1 and N2 were greater ( $P=0.01$ ) than on P2.

NUTRITIONAL EVALUATION OF VEGETABLE SOYBEAN AT DIFFERENT REPRODUCTIVE STAGES. I. CHINESE VEGETABLE SOYBEAN. Ali I. Mohamed, Harbans L. Bhardwaj, and M. Rangappa, Agricultural Research Station, Virginia State University, Petersburg, Va 23806. In 1990, a group of American soybean scientists from five historically black 1890 land grant universities visited several Agricultural Research Stations in the Republic of China (Taiwan) and the People's Republic of China (PRC). During this trip they collected 25 new sources of specialty vegetable-type soybeans germplasm. Twenty four genotypes were successfully grown at Petersburg, Virginia. These lines showed significant differences in mature seed size. Mean weight of 100 seeds was 32 g. Mean protein and oil percent was 42.05 and 19.11, respectively. Highly significant and negative correlation ( $r = -0.658^{**}$ ) was observed between protein and oil contents. The economical value (protein + oil) of AGS290, AGS 293, KVS 124, G9053, GC84136P418, BLUE SIDE, HENONG #33, HEFENG # 25, ZIHUA #4, MEINE #3, and N1589 was higher than 62%. The analyses of immature seeds showed significant differences in percent moisture, protein and oil, trypsin inhibitors, and lipoxygenase activities. The mean oil and protein content of immature seeds were 6.03 and 25.23 %, respectively. The mean Trypsin Inhibitor activity was 25.83 TI units for mature seeds and 423.83 TI units for immature ones. The mean lipoxygenase activity was 36720 units for mature seeds and 83126 units for the immature seeds. These genotypes are valuable editions to the USDA soybean germplasm collection.

EFFECT OF TWO DIETS UPON LIVER AND MUSCLE COMPOSITION IN HYBRID STRIPED BASS. Scott H. Newton, Virginia State University, Petersburg, VA 23806 and Mark Subramanyam, Zeigler Bros. Inc., Gardners, PA 17324. Levels of protein and fat in fish diets affects production performance and chemical composition of fish. One of the objectives of this study was to determine the chemical composition of hybrid striped bass fed high protein/high fat and low protein/low fat diets. Fish were stocked in earthen ponds (0.05 ha) at the rate of 7400 per hectare. Fish were fed for 195 days on either a 42% protein : 14% fat (A) or 33% protein : 4% fat diet (B) in triplicated ponds. The metabolic energy of diets A and B were 3.6 and 3.1 Kcal/g, respectively. Results of this study showed that fish raised on diet A had a significantly higher survival rate (83%) than those fed diet B (35%). Total lipids in livers of fish fed diet B were significantly higher than those of fish fed diet A. Glycogen (mg glucose/g liver) was higher in fish fed diet A (512) compared to diet B (319). There was a significant difference in body chemical composition between the two diets. Body lipid and protein for fish fed diet A were 51% and 43% (on a dry basis), and 40% and 55% for fish fed diet B, respectively. Lipid and protein content of fish fillets had a similar trend as with whole body composition. Fatty acid composition of fillets was significantly different between diets A and B. Fish performance and production was higher with the high protein/high fat diet, however, higher lipid and lower protein content was found. More research is needed to produce a diet capable of increasing survival and growth rate with hybrid bass body composition having high protein and low lipid content.

SEASONAL POND WATER TEMPERATURE RANGES FOR AQUACULTURE PRODUCTION USE IN SOUTHSIDE VIRGINIA. Scott H. Newton, Aquaculture Initiative, Virginia State University, Petersburg, VA 23806. Water temperature is the single most important factor affecting fish metabolic activities and growth. Pond water temperatures were recorded from aquaculture ponds (0.05 - 0.10 ha) located in Chesterfield County, Virginia over nearly a three year period from January 1989 through September 1991. Information on the biology of fish species along with aquaculture knowledge permits defining length of primary production periods for cultured fish. Water temperature information is used to delineate the production period for the three primary food fish (rainbow trout, channel catfish, and hybrid striped bass) which are presently being produced in Virginia. In Southside Virginia, aquaculture production periods are approximately 200 and 190 days, respectively, for warm and cold water fish species. Production cycle overlaps (at the start and end of periods) are due to seasonal weather variations.

BORON — THE MISSING ELEMENT? N. L. Powell, Crop and Soil Environmental Sciences, and F. S. Wright', USDA-ARS, Tidewater Agricultural Experiment Station, Suffolk, VA 23437. Boron is an essential element for plant growth and development. Because boron is not transported through the plant phloem it must be taken up from the soil through the root system of the plant. The recommended soil test level of boron for corn, cotton and peanut is 0.75 ppm or greater. Soils in the coastal plains area of Virginia contain 0.36 ppm or less of boron in the plow layer and 0.25 ppm or less below the plow layer. A Davidson clay in the piedmont section of Virginia contained 0.50 to 0.66 ppm of boron in the top 12 inches and 0.25 to 0.40 ppm between 12 and 18 inches below the soil surface. It is evident that several of our soils are boron deficient for row crop production. Application of boron to irrigated corn grown on the coastal plain soil resulted in dramatic grain yield increases during the 1990 and 1991 growing seasons when compared to the 1986 through 1989 growing seasons. The yield increases were attributed to the application of boron in the crop root zone thus stimulating better root development and more efficient use of water and applied fertilizer.

EFFECTS OF SALINITY ON YELLOW HYBRID STRIPED BASS AND ROTATING BIOLOGICAL CONTACTOR BIOFILTERS. Darin S. Prillaman & George S. Libey, Dept. Fish. & Wildl. Sci., Va. Polytechnic Institute & State Univ., Blacksburg, VA. 24061-0321. A 48 day study was conducted in three recirculating aquaculture systems containing yellow x striped bass hybrids to test the affects of increased salinity levels on the Rotating Biological Contactor (RBC's) biofilter performance. The salinity levels in the three systems were suddenly increased to 4, 7, and 13 ppt. Water temperature was 22 C. The fish were not adversely affected and the nitrifying bacteria adjusted in less than two weeks.

THE LIMITS OF SCIENTIFIC DISCOURSE: A CASE STUDY - THE INTRODUCTION TO VIRGINIA WATERS OF *CRASSOSTREA GIGAS*. Jane C. Webb and George R. Webb. Dept. of Physics and Computer Science, Christopher Newport University, Newport News, VA 23606. Charlotte Webb\*, Science Studies Ctr., Virginia Polytechnic Institute and State University, Blacksburg, VA 24061. Decisions of public policy concerning Chesapeake Bay fisheries involve four major participants: regulators, industry representatives, environmental action groups and scientists. From the scientists, each of the other three groups seeks data and models on which to ground its positions and, for the regulators, ultimately the base on which to manage and develop the resource. Virginia's Marine Resource Commission has just considered a proposal for the introduction of a non-native species, *Crassostrea gigas*, to the waters of the Chesapeake Bay. A case study of the process by which the Commission reached its conclusions demonstrates clearly that the scientists' code of strict objectivity and interpretation of opinions sought as requests for unassailable models renders scientists largely ineffectual spokespersons for both their considered scientific opinion and the policy position that they espouse.

## Archaeology

CULTURAL IMPLICATIONS OF LATE WOODLAND FAUNAL ASSOCIATIONS AT THE HEADWATERS OF THE ROANOKE RIVER. Michael B. Barber, Jefferson National Forest, 210 Franklin Rd SW, Caller Service 2900, Roanoke, VA 24001. Over the last twenty years, a number of Late Woodland sites at the headwaters of the Roanoke River have been excavated which produced an abundance of vertebrate faunal remains. At least 5 components from the period have been isolated with occupation dates ranging from ca. AD 1250 to ca. AD 1700. The recovered material lends itself to a study of changes in subsistence strategies through time. Currently analysed data is discussed along with hypotheses to be tested and research designs to be implemented. Finally, the available data is viewed at a more regional level.

THE PREHISTORY AND HISTORY OF THE SALTVILLE VALLEY, VIRGINIA: A CHRONOLOGICAL AND ECOLOGICAL DISASTER. Eugene B. Barfield, Jefferson National Forest, Roanoke, VA 24001. Throughout prehistory and history the natural resource salt has been an attractor to human and animal populations. The purity of salt deposits in the Saltville Valley, Virginia and the want for this resource for the last 11 millenia has led this small Appalachian community into an inevitable and ineludible ecological trap. Ca. 11,100 years ago the earliest North American human inhabitants were attracted to this valley. Salt requirements for herbivores made hunting relatively easy for humans here in prehistoric times. In past decades looted Indian burial goods indicate a more complex society having attained a Petty Chiefdom status. It is believed by this author that trading of salt was responsible for this status. Commercialization of the salt resource led to Civil War battles and the massacre of 52 members of the 5th U.S. Colored Calvary in 1864. Further commercialization of the resource led to manufacture of chemicals and by-products that have caused disaster and loss of life, E.P.A. Superfund areas, and yet unknown health problems in the community.

ARCHAIC AND WOODLAND LITHIC UTILIZATION IN THE ARNOLD VALLEY: ROCKBRIDGE COUNTY, VIRGINIA. Kimberly Lowe, Jefferson National Forest, Roanoke, Virginia 24001. The Arnold Valley, located in Rockbridge County, Virginia between the James River and the western toe slopes of the Blue Ridge Mountains is rich in history and prehistory. From the James River floodplain to the Blue Ridge Mountain crest some 3,000 feet higher in elevation Jefferson National Forest archaeologists have examined over fifty prehistoric and historic sites. Among these sites are two quarries, jasper and quartzite, both used in Late Archaic through Woodland Culture Prehistoric Periods. Diagnostic projectile points from Phase I surveys and Phase II excavations suggest no extensive habitation of humans before ca. 4,500 B.C. Temporal and type lithic usage will be studied in this paper. Upon future examinations of data from historic sites this valley will be eligible for nomination to the National Historic Register of Historic Places as the Arnold Valley Archaeological District.

BEYOND TRIGG: A REANALYSIS OF TRIGG SITE 44MY3 AND OTHER RELATED SITES. Maureen E. Siewert, Radford University, Department of Sociology/Anthropology, Radford, VA 24142. The Late Woodland/Protohistoric Trigg site (44MY3) was excavated in 1975. A report on this work was prepared by Buchanan in 1985. Other analyses of this palisaded Indian village include Sternheimer's 1983 mortuary study. Recent excavations east of Trigg along the New River at sites 44MY438 and 104 have uncovered prehistoric Indian remains comparables to the Trigg remains. In addition, the 1990-91 excavation of the Graham-White site in Salem, VA, another protohistoric Indian site, shed new light on the culture of Southwestern Virginia Native Americans of the period of early European contact. Because of these recent excavations, this paper will reexamine 44MY3 in relation to 44MY438 and 104, as well as the Graham-White site. These sites will be compared in terms of their lithic and pottery remains, and trade goods, where applicable. Finally, this reexamination will then be related to other sites in the Southwestern Virginia region as a whole.

### Astronomy, Mathematics and Physics

FUNDAMENTALS OF GENERAL SCIENCE. Joshua C. Anyiwo, Department of Physics and Computer Science, Christopher Newport University, Newport News, VA 23606. Before Bacon's "Novum Organum", which ushered in our contemporary Western Science, yes, even before Aristotle's "Organon", which formally established knowing as a thinking process, there existed a unified canon of thought, general science, in terms of which a complete knowledge of all and everything could be extracted. While it is not synonymous with general-system theory, general science implies the concept of the general-system, and in its complete form, projects all the elements necessary for the analysis of the general-system. This paper presents the foundation of an authentic general science in terms of the definitions of "knower", "knowing" and "knowledge". Implicit in this general science is a unification of Eastern mysticism, Western positivism and all the other formal and informal sciences in recorded history, a unification which is rapidly coming to the attention of many Western scientists.

RESONANT ENERGY TRANSFER AND THERMALIZATION IN TM,Ho:YAG. A.M.Buoncristiani, Physics Department, Christopher Newport College, Newport News, VA 23606 and G. Armanag\*, Physics Department, College of William and Mary, Williamsburg, VA 23185.

In the course of studying energy transfer between levels in sensitized dielectric crystals we have come across an interesting illustration of the approach to equilibrium between resonant levels in two different ions. Observation of this effect, we think for the first time, is possible because of the unique character of the resonance and the relatively slow rate of energy transfer involved. The system is crystalline Yttrium Aluminum Garnet (YAG),  $Y_3 Al_5 O_{12}$  with Tm and Ho substitutionally doped into a small percentage of the yttrium sites. The crystal fields experienced by the dopant ions are responsible for the observed optical properties. We present evidence for the exchange of energy between two levels, Tm $[^3F_4]$  and Ho $[^5I_7]$ , following the excitation of Tm with a diode laser ( $\approx 785$  nm). By examining the temporal behavior of emission patterns from different spectral regions we can study the approach to equilibrium. Using a simple model of the transfer processes, the equilibration time ( $200 \mu\text{ sec}$ ) and equilibration energy ( $560 \text{ cm}^{-1}$ ) are determined. (Supported by NASA Grant NAG 1-796.)

PHYSICS INSTRUCTION IN CHINA AND JAPAN. D. Rae Carpenter, Jr., Dept. of Physics and Astronomy, Va. Military Inst., Lexington, VA 24450. The Second US/China/Japan Conference on Physics Education was held in Fuji Japan last July. An overview of that conference will be given along with slides and observations of physics teaching in China as seen in visits to physics departments in ten Chinese colleges and universities in September 1990. Similarities and differences compared to the U.S. will be highlighted. Increased trilateral cooperation stressed in the conference will be elaborated upon.

FINAL-STATE-INTERACTION EFFECTS ON THE QUASI-ELASTIC PEAK FOR PROTON-NUCLEUS SCATTERING. Rajendra Dubey & G. S. Khandelwal, Dept. of Physics, Old Dominion Univ., Norfolk, Va. 23529, & F. A. Cucinotta\*, Space Systems Div., NASA Langley Res. Ctr., Hampton, Va. 23665-5225. Quasi-elastic proton-nucleus scattering is considered in the high energy optical model. Energy loss and momentum transfer spectra for projectile ions are evaluated in terms of an inelastic multiple scattering series corresponding to multiple knockout of target nucleons. Calculations using harmonic oscillator shell model wavefunctions and model response functions are compared to experiments.

A DENSITY CORRECTION TO HIGH ENERGY ION STOPPING. Hamidullah Farhat and G.S. Khandelwal, Department of Physics, Old Dominion University, Norfolk VA 23529, J.L. Shinn and J.W. Wilson, NASA Langley Research Center, Hampton, VA 23665. In determination of stopping power of high energy ions an approximate density - effect correction has been evaluated. The Bethe - Bloch stopping power formula has been modified to account for the reduction in ionization caused by polarization of the medium and the determination of ionization produced by ions of high energies. Although only the density - effect correction to stopping power of proton in some material is presented here, the conclusions obtained are valid for other charged particles too.

## MODELING ELECTRIC FIELDS IN TWO DIMENSIONS USING COMPUTER AIDED DESIGN.

Douglas W. Gilmore, Dr. Kevin Giovanetti, Dept. of Physics, James

Madison Univ., Harrisonburg, VA 22807. We describe a method for analyzing static electric fields in two dimensions using AutoCAD. The algorithm is coded in LISP and is modeled after Coulomb's Law. The software platform allows for facile graphical manipulations of field renderings and supports a wide range of hardcopy-output and data-storage formats. More generally, this application is representative of the ability to analyze data that is the solution to known mathematical functions with computer aided design (CAD).

A STUDY OF THE IRON-ZINC INTERMETALLICS IN GALVANNEAL STEEL COATINGS. Richard G. Grant and Desmond C. Cook, Department of Physics, Old Dominion University, Norfolk, Va, 23529. The study of four metal powder galvanneal standards using Mössbauer spectroscopy has shown that the main iron-zinc intermetallic phases, Zeta, Delta, Gamma-1 and Gamma are easily distinguishable from each other. It is particularly evident that the Delta and Gamma-1 phases, which are predominant in commercially produced galvannealed steel coatings and which cannot be separately identified by X-ray analysis, produce very different Mössbauer spectra. Mössbauer spectroscopy therefore is the only technique presently able to make this identification. Each phase is paramagnetic at room temperature with the Zeta phase containing one iron site. The Delta and Gamma phases contain two and the Gamma-1 phase contains three iron sites. The site occupancy in each phase appears to vary as a function of iron content across the phase diagram thereby making phase identification in galvanneal coatings difficult.

AMORPHOUS PREPARATION OF HIGH TEMPERATURE SUPERCONDUCTING COMPOUNDS. Thomas C. Inslee, C. M. Castevens and S. L. Herr, Dept. of Physics, Va. Commonwealth Univ., Richmond, Va. 23284. We have prepared superconducting  $Y_1Ba_2Cu_3O_{7-x}$  and ferromagnetic  $La_2CuO_4$  by evaporating aqueous solutions of metal-organic precursors to obtain fine powders. These powders were then decomposed, pressed, and sintered to produce polycrystalline pellets. Pellets from the series of metal oxides  $(La, Ba)_1(Cu, Mn)_xO_x$  were prepared in the same way. Unlike  $Y_1Ba_2Cu_3O_{7-x}$  and  $La_2CuO_4$ , which can also be prepared using other techniques such as the sintering of dry oxide powders, the full series  $(La, Ba)_1(Cu, Mn)_xO_x$  has only been successfully prepared by using the technique described in this poster. Characterization of the samples using scanning electron microscopy and X-ray diffraction has shown that they are highly homogenous, single-phase materials with no deviation from the desired stoichiometry. Our results show that this technique can be an effective method for preparing metal oxide superconductors containing from three to five elements, providing that the corresponding metal-organic precursors are at least sparingly soluble in water.

PLASMA DYNAMICS IN A HYPOCYCLOIDAL PINCH DEVICE. Jong H. Kim, Kwang S. Han and Ja H. Lee<sup>1\*</sup>, Dept. of Physics, Hampton Univ., Hampton, Va. 23668. Plasma velocity in the run-down phase of the hypocycloidal pinch (HCP) device, which generates a hot and dense plasma, was investigated. Numerical calculations with a mass fraction in the snowplow model for the pressure range of 10 mTorr to 100 mTorr helium gas in the HCP are compared with experimental velocity of the plasma. It was found that a large mass leak rate, around 85%, has to be used to explain the measured plasma velocity. In addition for the pinched plasma in the HCP, the predicted plasma parameters such as temperature and density will be compared with spectral data. (Supported by ARO grant number DAAL03-89-0113 and NASA grant number NAG 1-970.)

1. Adjunct Professor, Dept. of Physics, Hampton Univ. & Senior Scientist, NASA Langley Research Center, Hampton, Va. 23665.

COMPUTER INTERFACED PLASMA DIAGNOSTICS. Michael V. Kirk, Matthew A. Willis, Timothy M. Persons and Gerald R. Taylor, Jr., Physics Department, James Madison University, Harrisonburg, VA 22807. The properties of a low energy argon plasma were measured with electric probes. Data acquisition and control of the experiment used a 386 computer with D/A and IEEE-488 interfaced instrumentation. Plasma temperature and electron energy distribution of a low density plasma were analyzed using a spreadsheet. The applicability of using spreadsheets for plasma diagnostics will be discussed.

APPROXIMATION WITH NURBS. Maria H. Lam, Department of Computer Science, Hampton Univ., Hampton, Va. 23668. The Boeing Airplane Company has used rational B-spline and has successfully established it as an IGES standard for curve and surface definition. Developers of aero/hydrodynamic applications are encouraged to switch to non-uniform rational B-spline (nurbs) if they currently use some other form of math model. We use a non-uniform rational B-spline to approximate a design of a wing section of an aircraft. A shape-preserving quadratic spline that we have developed earlier is used to interpolate data points representing the upper and lower wing section. The data is obtained from the design model which is not in nurbs form. A Bézier form of nurbs is then generated to approximate the interpolating curves to a desired degree of accuracy. Result of this investigation will be presented. This work is supported by NASA under grant NAG-1-948.

THE LET RESPONSE OF A MICRODOSIMETER. Duc M. Ngo and G. S. Khandewal, Dept. of Physics, Old Dominion Univ., Norfolk, VA 23529 & J. W. Wilson and F. A. Cucinotta, NASA Langley Research Center, Hampton, VA 23665. An algorithm for the derivation of LET response of the microdosimeter to radiation fields in space is described which is based on assumptions that the LET is constant as a particle passes through the sensitive volume, the chord length distribution is known, and the delta-ray is neglected in the sensitive volume. It is applicable to the spherical and cylindrical proportional counter. The event spectrum is dependent on the geometric shape of the microdosimeter volume.

DESIGN OF AN INEXPENSIVE PARALLEL-PROCESSING COMPUTER FOR IBM-PC-TYPE COMPUTERS. Joseph W. Rudmin, Dept. of Physics, James Madison Univ., Harrisonburg, VA, 22807. Because of the combination of low power consumption and small size, the Signetics 87C751 microcontroller is ideally suited for some types of parallel information processing. A printed circuit board is being designed which will incorporate fifty-seven processors onto a card for insertion into a PC IO Channel. The computer consists of seven nodes. Each node consists of seven 87C751 processors under control of a Dallas Semiconductor DS5000T single-chip computer. The seven nodes are controlled by an eighth DS5000T which is in turn under control of the PC. Because the DS5000T computers each have their own internal memory and battery backup for both program code and data, the card will be able to retain programs and data when the host PC is turned off, or even when the card is moved from one PC to another. The 87C751s each have 2 kbytes of program space, so they must be programmed for specific applications in advance, with the node-master calling the pre-programmed subroutines. The cards would provide an interesting platform for parallel computation, logic, and for studying parallel processing.

VARIATION IN OZONE CONCENTRATION IN THE VICINITY OF WALLOPS ISLAND, VA. Edgar Russell\* and Demetrius D. Venable, Department of Physics, Hampton University, Hampton, Va. 23668. We have investigated variations in ozone concentrations in the vicinity of Wallops Island, Va. in support of the Colorado Space Grant Consortium Student Ozone Atmospheric Rocket Project. We are providing Spacecraft verification for the sounding rocket project using data from the SAGE II satellite. Data were evaluated for the period 1985 through 1990. Our findings show (1) a slight increase in total ozone concentration as North latitudes increase; (2) a slightly higher total ozone concentration in summer than in winter; (3) the peak in the ozone profile as a function of altitude occurs slightly closer to the earth's surface during winter; and (4) no apparent changes from year to year for the period examined. Assistance was provided by the Virginia Space Grant Consortium and NASA Langley Research Center. (Supported by NASA Grant NAG-1-1091)

MUONIUM AND MUONIC RADICAL FORMATION IN BUCKMINSTERFULLERENE. C.E.Stronach and R. S. Cary\*, Physics Dept., Va. State Univ., Petersburg, Va. 23806, E. J. Ansaldi\* and J. J. Boyle\*, Univ. of Saskatchewan, Saskatoon, SK, Canada, C. Niedermayer\*, Univ. Konstanz, Konstanz, Germany, G. D. Morris\* and J. H. Brewer\*, Univ. of British Columbia, Vancouver, BC, Canada. Three distinct electronic states were detected for  $\mu^+$  after implantation into a  $C_{60}$  sample. About 60% of the  $\mu^+$  remained in the bare (diamagnetic) state, essentially an interstitial charged point particle. The rest of the muons were found to thermalize predominantly in two muonium ( $Mu = \mu^+e^-$ ) atomic species: a "vacuum" Mu state, with hyperfine coupling close to that of free Mu (perhaps at the molecular center), and a muonium substituted radical, i.e., a hydrogen-like Mu addition to double bonds on the carbon rings. This opens up a rich subfield of fullerene spectroscopy using muons. The diamagnetic  $\mu^+$  will allow the study of the superconducting (doped) cases. Muonium, as the muonated radical, will serve to map out the electron spin density in the rings, and as vacuum muonium on and near surfaces (molecules or grains), to study surface reactions with other absorbed species. This work was supported by the NRC and NSERC of Canada, and by the US DOE (CES) and NASA (RSC).

MUON SPIN ROTATION STUDIES OF LAYERED AND SUPEROXYPHENATED HTSC AND RELATED COMPOUNDS. C. E. Stronach, D. R. Noakes\*, R. S. Cary\* & M. R. Davis\*, Physics Dept., Va. State Univ., Petersburg, Va. 23806, E. J. Ansaldi\*, Univ. of Saskatchewan, Saskatoon, SK, Canada, C. Niedermayer\* and H. Glückler\*, Univ. Konstanz, Konstanz, Germany, T. M. Riseman\* and K. Chow\*, Univ. of British Columbia, Vancouver, BC, Canada, X. Obradors\*, A. Fuertes\* and B. Martinez\*, Institut de Ciencia de Materials, Barcelona, Spain. Measurements of the  $\mu^+$  spin rotation and depolarization reveal that  $La_2SrCu_2O_{6+\delta}$  and  $La_2CaCu_2O_{6+\delta}$  display magnetic ordering similar to that of  $La_2SrCuO_4$ , and  $YBa_2Cu_3O_x$ . Superconductivity was detected in  $La_2CaCu_2O_{6+\delta}$  ( $\delta \geq 0.05$ ), with the onset near 45K and accompanied by a change in the  $\mu^+$  spin precession signals from the majority AFM phase. This was not seen in  $La_2SrCu_2O_{6+\delta}$ . This behavior was attributed to mobility and local clustering of intercalated oxygen excess in the layer between the  $CuO_2$  planes.

This work was supported by the NRC and NSERC of Canada, CI-CYT and the Midas project in Spain, and by the US DOE (CES & MRD) and NASA (RSC).

MÖSSBAUER EFFECT ANALYSIS OF THE LOW TEMPERATURE HELI-MAGNET, IRON MONOPHOSPHIDE. Gary R. Sutherland, Mina Nozar, Jerry W. Skaggs, Jr., Stefan J. Kloc, Ru Z. Zhao and Desmond C. Cook, Department of Physics, Old Dominion University, Norfolk, Va. 23529. A study of the crystal structure and the magnetic hyperfine interactions in iron monophosphide has shown that magnetic ordering occurs at 118.9 K. This is contrary to many reported bulk magnetic studies which conclude that FeP, is either paramagnetic down to 30 K, or exhibits a weak magnetism due to impurities. The Mössbauer effect shows that the magnetic ordering occurs between the iron atoms and that the exchange interaction between nearest neighbor iron atoms is very weak. The saturation hyperfine magnetic field is only 3.80 T and the temperature dependence of the field is well explained by simple MFT. The magnetic moments align in the a-b plane of the distorted orthorhombic structure with the electric field gradient parallel to the crystalline c-axis. The quadrupole splitting is slightly temperature dependent. It is apparent that two magnetically inequivalent sites are present, thereby supporting the possible existence of a helimagnetic structure.

#### THE EFFECT OF GLASS SLEEVES ON A Nd:YAG LASER EFFICIENCY.

Kimberly Washington, In H. Hwang and Kwang S. Han, Dept. of Physics, Hampton Univ., Hampton, Va. 23668. The efficiency enhancement of a Nd:YAG laser by glass sleeves with different thicknesses has been studied in this limited experimental condition. Theoretical consideration has been made based on the geometrical optics. (Supported by the Virginia Space Grant Consortium.)

TRANSPORT DUE TO IDEAL MHD MODES IN TOKAPOLE II. Eric White and Alkesh Punjabi, Hampton Univ., Hampton, Va 23668. Based on the analysis of results in the Tokapole II experiments, we have constructed the spectrum of the ideal magnetohydrodynamic (MHD) perturbations in this device. We use this spectrum to evaluate the transport of electrons in Tokapole II due to ideal MHD modes. The Monte Carlo Method for transport in toroidal plasmas as developed by Punjabi and Boozer [1] is employed. The preliminary results of this investigation will be presented. This research supported by DOE under the grants DE-FG05-88ER53265 and DE-FG05-90ER54106

[1] Punjabi A., Boozer A., Lam M., Kim M. and Burke K., J. Plasma Phys., 44, 405-430 (1990)

THE CONVERSION EFFICIENCY OF PHOTOVOLTAIC CONVERTERS WITH A PULSED LASER. Kyongchul Woo and Nelson W. Jalufka and Ja H. Lee<sup>1</sup>, Dept. of Physics, Hampton Univ., Hampton, Va. 23668. A study of conversion efficiencies of photovoltaic converters (Si, GaAs) for a pulsed ( $\approx 1$  ns) dye laser pumped by a nitrogen laser was performed. The conversion efficiency was measured for different wavelengths of a pulsed dye laser to verify the optimum wavelength, 1.13  $\mu\text{m}$  for Si and 0.87  $\mu\text{m}$  for GaAs, expected from the band gaps of the photovoltaic converters. A significant reduction of the conversion efficiency from that for CW inputs is noted. The study will provide a database for estimating the efficiency of pulsed-laser power beaming to remote spacecraft. (Supported by NASA grant number NAG 1-1110.)

1. Adjunct Professor, Dept. of Physics, Hampton Univ. & Senior Scientist, NASA Langley Research Center, Hampton, Va. 23665.

## Biology

GENETIC VARIATION IN THE BEACH CLAM DONAX REVEALED BY THE RAPD AMPLIFICATION OF GENOMIC DNA. Laura Adamkevicz, Department of Biology, George Mason University, Fairfax, VA 22030. The RAPD technique uses a short (9 to 12 base), random-sequence primer with the polymerase chain reaction to amplify genomic DNA. The result is a pattern of between one and six fragments of DNA ranging from about 0.4 to 2.0 kilo bases in length, a different pattern being generated by each primer sequence. These patterns are similar in principle to restriction fragment length polymorphisms and provide investigators with a new source of genetic markers. Screening a panel of 20 random primers with genomic DNA from 4 species of donacid clams revealed extensive polymorphism within species and clear differentiation among species. Of those primers that produced reliable results, every one revealed at least one polymorphism. Sometimes these polymorphisms were shared among species, but few fragments were found to be common to all four taxa. This RAPD technique has great promise for resolving questions about distinctness of species, and it should lend itself to the construction of phylogenetic trees within genera.

Directionality Patterns, Sound Pressure Levels, and Individual Variation of Vocalizations from the Oyster Toadfish, *Opsanus tau*. John F. Barimo and Michael L. Fine (\*), Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. Courtship boatwhistle calls of individually identified male *Opsanus tau* were recorded in the York River, VA with two calibrated hydrophones and a waterproof recording system. Boatwhistles propagated in a modified omnidirectional pattern, which was bilaterally symmetrical. The Sound Pressure Level (SPL) at 1 m was 3-6 dB higher caudal ( $180^\circ$ ) than rostral to the fish ( $0^\circ$ ). SPL was reduced 1-2 dB at  $\pm 40-50^\circ$ , after which levels increased steadily to  $180^\circ$ . The mean SPL of the boatwhistle was 126 dB (re 1  $\mu$ Pa) at 1 m  $0^\circ$  with a 5-9 dB range in individual variation, compared to 123 dB for the agonistic grunt. The mean fundamental frequency of the boatwhistle was 249 Hz with an individual variation of 0-10 Hz. Mean boatwhistle duration was 272 ms with an individual variation of 64-164 ms. Variation of these parameters indicates that neural control of SPL and fundamental frequency is similar and both are more tightly controlled than duration. (Supported by grants from Sigma Xi and the VCU Undergraduate Research Program.)

THE EFFECTS OF DILUTED DIETS AND A SHORTENED PHOTOPERIOD ON RESOURCE ALLOCATION IN THE FRESHWATER SNAIL *PHYSA FONTINALIS*. Amy Bateman, Elsa Q. Falls, and Arthur F. Conway, Dept. of Biol., Randolph-Macon Col., Ashland, VA 23005. Resource allocation in the freshwater snail *Physo fontinalis* was investigated using various cellulose dilutions of artificial diets and photoperiods of 16L/8D and 12L/12D. *P. fontinalis* showed maintenance of rates of assimilation, tissue growth, and shell growth when nutrients were diluted by 50% and 75%. Comparisons were made between resources allocated to growth and reproduction. In 16L/8D neither was favored in terms of weight per gram of dry snail tissue. In 12L/12D growth was favored to reproduction in terms of weight per gram of dry snail tissue; however, the numbers of eggs produced were greater than those produced in 16L/8D. The ability to maintain physiological processes under nutrient stress supports the theory of compensation which suggests that these snails normally operate at submaximal rates. Shifts in resource allocation appear to be safety measures which anticipate shortages.

A COMPARISON OF THE LEVEL OF FEMALE REPRODUCTIVE INHIBITION IN WHITE-FOOTED MICE *PEROMYSCUS LEUCOPUS NOVEBORACENSIS* FROM MICHIGAN AND VIRGINIA. Timothy S. Boyer and C. Richard Terman, Lab. of Endo. & Pop. Ecol., Dept. of Biol., Col. of William and Mary, Williamsburg, Va. 23185. Studies of Michigan and Virginia *P.l.n.* have demonstrated contradictory data with regard to the level and presence of female induced reproductive inhibition. This phenomenon was reexamined in a comparative study using outbred lab colonies developed from mice captured near East Lansing, Michigan and Williamsburg, Virginia. Newly weaned 21 day old females from each colony were raised in the presence of either a strange proven adult male or a strange proven adult bisexual pair. Results demonstrate that 71% of young females reared in the presence of a bisexual pair were pregnant or had produced a litter by 150 days of age. This reproductive level was not different from that observed with young females reared with only a strange male. In addition, no significant difference was observed across treatment groups in vaginal perforation age or age at first litter. These results do not support a high level of adult female induced reproductive inhibition in *P.l.n.*. Variations in previously reported data appear not to be due to any intrinsic differences in the Michigan and Virginia animals.

## DISTRIBUTION OF LONG-TAILED SHREWS IN NORTHWESTERN FAIRFAX COUNTY.

Walter Bulmer, department of natural science, Northern Virginia Community College, Annandale, VA 22003 & Peter King, department of biology, George Mason University, Fairfax, VA 22030. Exact distribution of species of genus Sorex is not established in northern Virginia, particularly with respect to the overlap of habitats of S. hoyi, S. cinereus, S. fontinalis, and S. longirostris. There is some controversy as to whether S. fontinalis is a subspecies of S. cinereus. A series of pitfall traps was established in extreme northwestern Fairfax county from March to July, 1991. Both upland forest edge and river floodplain sites were sampled. Both yielded S. longirostris but no other species of Sorex. Of other shrew genera, only Blarina was found. 23 S. longirostris were collected during a total of 2380 trap nights. Animals collected were measured and entered into the mammal collection at N.V.C.C. Data for air pressure, humidity, temperature and moon phase were collected in order to correlate activity of these animals to atmospheric conditions.

IMMUNE AND PARAimmune COMPONENTS ASSOCIATED WITH LIPOPOLYSACCHARIDE-INDUCED MURINE RESORPTION J. C. Burnett and A. F. Conway, Dept. of Biol., Randolph-Macon Col., Ashland, Va., and C. M. Conway, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. CD-1 mice were used to study resorption (abortion). Injection of 10 ug Lipopolysaccharide (LPS) into the tail vein of pregnant females on the ninth day of gestation caused 100% resorption (versus 10% in saline-injected control females). LPS injection caused a 3.0 g mean decrease in reproductive track weight ( $p=0.002$ , Scheffe) and a 6.7 g mean decrease in body weight ( $p=0.043$ , Scheffe) relative to controls, but caused no statistically significant changes in lymph node or spleen weights. Immunohistochemistry demonstrated significantly increased ( $p<0.05$ , Mann-Whitney U) numbers of presumed natural killer cells (asialoGM1<sup>+</sup> and endogenous peroxidase<sup>+</sup>) and T lymphocytes (thy 1.2<sup>+</sup>) near the myometrium of the mesometrial region in implantation sites from LPS-injected females. Significantly increased numbers of presumed macrophages (mac-1<sup>+</sup>) were observed in the decidua near the myometrium and at the surface of the embryonic trophoblast in the mesometrial region of the uterus. These results indicate that LPS stimulates primarily paraimmune mechanisms and that macrophages are the most abundant potentially cytotoxic maternal cells at the surface of the embryo during resorption.

THE HOMOGONIC LIFE CYCLE OF STRONGYLOIDES ROBUSTUS, AN INTESTINAL PARASITE OF SQUIRRELS. Ralph P. Eckerlin, Natural Sciences Div., Northern Virginia Cmty. Col., Annandale, VA 22003. The homogonic life cycle of Strongyloides robustus, a nematode parasite of squirrels, was completed in the laboratory and life cycle stages are described. Eggs from naturally infected gray squirrels, Sciurus carolinensis, were cultured to yield rhabditiform first stage larvae which hatched in 3 hrs and molted to the second stage after 12 hrs or more at room temperature. Considerable growth and development occurred during the second stage. The esophagus changed from the rhabditiform to the filariform type before the second molt occurred at 46 or more hours. The quadrifurcate filariform third stage larva was an active swimmer and was the infective stage for the vertebrate host. Larvae penetrated unbroken skin, often at a hair follicle. Golden hamsters, Mesocricetus auratus, served as suitable experimental hosts. Larvae migrated from the skin and were found in the blood and lungs within 24 hrs. They reached the small intestine within 48 hrs. The first parasitic molt occurred in the small intestine at 84 hrs to a larva with a pointed tail. The reproductive system assumed the adult outline but was not yet functional. The second parasitic molt occurred at 144 hrs, also in the host intestine. Adult parthenogenetic females with characteristic knobbed tails became ovigerous on day 6 but eggs did not appear in the host feces until day 7.

**SURVIVAL AND MOVEMENTS OF RELOCATED SNOWSHOE HARES (*LEPUS AMERICANUS*) IN WESTERN VIRGINIA.** Michael L. Fies, Va. Dept. of Game & Inland Fisheries, 1229 Cedars Court, Charlottesville, VA 22903. During the early 1900's, snowshoe hare populations in Virginia were severely reduced by logging activities and the repeated burning of areas once forested with red spruce (*Picea rubens*). Presently, snowshoe hares are known to exist in Virginia at only a single site in Highland County. The purpose of this study was to determine if the native snowshoe hare subspecies (*L. a. virginianus*) could be trapped in nearby West Virginia and successfully relocated into suitable Virginia habitats. During the winters of 1988-89 and 1989-90, 26 snowshoe hares were live-trapped in West Virginia and relocated to the Laurel Fork area of Highland County, Virginia. Radio telemetry was used to determine movement patterns and causes of mortality. Only 2 hares (7.7%) survived longer than the life span of their transmitters. The other 24 hares survived an average of 23.8 days post-release. The primary causes of mortality among released hares were predation by bobcats and predation by unknown predators. Bimonthly survival rates were lowest during the March-April time period. The average home range size of snowshoe hares surviving more than 30 days (N=8) was 78.9 ha. The mean distance between consecutive locations for all hares was 540.9 m. Unusually mild winter weather with below-average snowfall accumulations was believed to have contributed to poor trapping success and high post-release mortality.

**TERMITES RESPONSE TO PALATABLE PROTOZOICIDES.** Robert L. Frank & Deborah A. Waller. Biol. Dept., Old Dominion Univ., Norfolk, VA 23529. Elimination of symbiotic gut protozoans might provide an effective control of termite pests. The objective of this study was to develop a protozoicidal termite bait that was preferred by termites over natural food sources. We tested termite response to a 1% tetracycline/5% urea solution (w/v) and to control solutions (water or 1% tetracycline) applied to filter paper in no-choice and choice experiments. Two replicates of 100 termite workers from each of five colonies were prepared per treatment in each experiment. Experimental units were maintained in incubators for three weeks at 22-24°C and then measured for termite survivorship, termite dry weight, number of gut protozoans and amount of filter paper consumed. In no-choice tests, termites had significantly greater survivorship, dry weight, protozoan number and food consumption in control units than in treatment units. In choice tests, termites ate significantly more water-treated filter paper than tetracycline/urea-treated paper, but they ate more tetracycline/urea-treated paper than paper treated with tetracycline alone. In conclusion, the tetracycline/urea treatment solution is an effective protozoicide that is more palatable than tetracycline alone, but it is less palatable than water-treated controls.

**THE EFFECTS OF ETHANOL ON TRANSFECTED SCHWANN CELLS.** Berthie Labissiere, Sonya Moore, Alberta Springer, Dr. Phillip Archer\*, Dr. Regina Knight\*, Dept. of Life Sciences., Va. State University., Petersburg, Va. 23803. Primary Schwann cells transfected with the SV-40 T antigen gene provides a model for obtaining cells that express properties associated with normal Schwann cells in culture. Ethanol (ETOH) has been reported to have severe effects on the nervous system, which may lead to fetal alcohol syndrome or alcohol-associated peripheral neuropathy. The effects of various concentrations (conc.) of ETOH on the morphology and protein synthesis of the transfected Schwann cells were investigated. Cells with the highest conc. of ETOH (172mM) had the lowest cell count and protein conc. post 72 hr. Cells treated with 86mM of ETOH had over 70% more cells than the 172mM cells and nearly 40% less protein than the control. The 43mM ETOH conc. cells had 75% and 94% more cells present than the 86mM and 172mM conc. respectively and 26% less protein than the control. The 22mM ETOH conc. cells had 52%, 88%, and 97% more cells present than the 43mM, 86mM, and 172mM conc. of ETOH, also there was 55% less protein than the control. Light microscopic evaluation revealed cellular processes that thickened as the ETOH conc. increased.. Transfected Schwann cells provide an excellent model for studies of neuropathological reactions to ETOH in normal Schwann cells.

EFFECTS OF AGE AND PARITY ON THE DISTRIBUTION OF IMMUNOGLOBULINS IN THE PREGNANT MURINE REPRODUCTIVE TRACT. Sean I. W. Malone, Hugh C. Palmer, Jr.\*<sup>1</sup>, Kathleen M. Kennedy\*, and Carolyn M. Conway, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. Immunoperoxidase staining was used to localize maternal immunoglobulins (Igs) in implantation sites in female CD-1 mice of different age and parity classes (3 and 12 months old at 1st parity; 8 months old at 1st, 2nd, and 3rd parities). At 12.5 days of gestation, Ig's were found in the myometrium, decidualized myometrium, decidua basalis, trophoblastic giant cells, placental labyrinth, Reichert's membrane, and outer and inner yolk sacs. IgA staining intensity increased as a function of parity and decreased as a function of age. IgG staining intensity also increased as a function of parity but remained constant as a function of age. IgM staining intensity increased from 1st to 2nd parity but then decreased from 2nd to 3rd parity. IgM staining intensity increased as a function of age in maternal tissues but decreased as a function of age in embryonic/fetal tissues. The parity-associated increase in IgA and IgG in implantation sites correlated with an increase in viable offspring in older mice at 2nd and 3rd parities. The age-associated changes in IgM and IgA in implantation sites correlated with a decline in litter size in older females.

THE ROLE OF SEASONAL LYSOSOMAL ACTIVITY IN THE MECHANISMS OF COLLAGEN DEGRADATION IN THE OCTOCORAL LEPTOGORGIA VIRGULATA (COELENTERATA: GORGONACEA). Eric W. Melaro and Roni J. Kingsley, Dept. of Biology, Univ. of Richmond, Richmond, VA 23173. Leptogorgia virgulata, an octocoral or gorgonian (sea whip) found in marine waters, is an invertebrate species possessing an abundance of calcium carbonate spicules. Seasonal variation of the collagenous matrix component of these spicules has been proven biochemically and ultrastructurally, with levels noticeably higher in summer compared to winter months. This seasonal fluctuation in collagen content suggests that some demineralization and subsequent remodelling of the calcium carbonate spicules takes place throughout the year. It is suggested that an increase in lysosome abundance and associated enzyme activity might be involved in the seasonal turnover and decalcification. This study provides evidence for a cycle of lysosomal enzyme activity via histochemical enzyme localization. Analysis of acid phosphatase levels in the spicule-containing mesoglea reveals greater enzyme activity in late winter samples (February), with minimal activity observed in early summer specimens (June). This clearly coincides with earlier work stating that peak collagen removal occurs in late winter.

GENETIC VARIATION IN EASTERN FOX SQUIRRELS, INCLUDING POPULATIONS OF THE ENDANGERED DELMARVA FOX SQUIRREL (SCIURUS NIGER CINEREUS). Nancy D. Moncrief<sup>1</sup> and Raymond D. Dueser<sup>2</sup>. <sup>1</sup>Virginia Museum of Natural History, Martinsville, VA 24112, and <sup>2</sup>Dept. of Fisheries and Wildlife, Utah State Univ., Logan, UT 84322. We compared genetic variation within and among populations of fox squirrels (Sciurus niger) using data from 41 presumptive genetic loci assayed by horizontal starch-gel electrophoresis. The primary focus of this study was two populations of Delmarva fox squirrels (S. n. cinereus) from the Eastern Shore of Maryland and Virginia as well as populations of fox squirrels from western Maryland, western Virginia, and Georgia. Allozymic variation in the Delmarva fox squirrel populations we analyzed is comparable to that found in other populations of eastern fox squirrels and in populations of fox squirrels from the lower Mississippi River valley. Additionally, these two S. n. cinereus populations possess an electrophoretically detectable genetic attribute (MPI') not present in any other population of S. niger examined to date. Evolutionary relationships among fox squirrels (including Delmarva fox squirrels) that inhabit the Gulf and Atlantic coastal plains will be described and discussed.

CHARACTERIZATION OF A TRANSFORMED SCHWANN CELL LINE. Sonya R. Moore, Berthie Labissiere, Alberta Springer, Dr. Phillip Archer\*, Dr. Regina Knight\*, Dept. of Life Sciences, Va. State Univ., Petersburg, Va. 23803. Neonatal rat Schwann cells were originally transfected with the SV40 papovavirus at Medical College of Virginia (Tennekoon, 1987.) The insertion of the virus provided a continuous source of Schwann cells which could be used as a model for studying properties of Schwann cells in vivo. The exact insertion is not known. This study was conducted to better characterize this transformed cell line. Giemsa banding techniques were used to compare karyotypes of this transformed cell line to normal rat cell karyotypes and karyotypes from another established transformed Schwann cell line. Northern blots were done to better characterize Po, a Schwann cell protein, synthesis by these cells. The karyotypes and Po expression gives supportive evidence for the transfected cells to be used as an in vitro model for studying Schwann cell function.

NEUTRAL RED STAINING OF LARVAL AND ADULT PROTHORACIC GANGLIA OF *MANDUCA SEXTA*. J. A. Morlang and F. H. Gray, Dept. of Biology, Hollins College, Roanoke, VA 24020. Biogenic amine-producing cells on the ventral surface of the prothoracic ganglion of the tobacco-hornworm, *Manduca sexta*, were stained with neutral red. Larval and adult aminergic cell distributions were compared and found to differ. In the adult, three to four relatively large cells (~0.1mm) stained consistently in the lateral posterior area of the prothoracic ganglion, as well as 12-15 smaller cells scattered in the lower half of the ganglion. The number of neutral red staining cells in the larvae was highly variable (14-35+), especially after the larvae reached a growth of 4cm in length and 7mm in width. Unlike the adult cells, the larval cell size (~0.025mm) was more consistent and cells stained throughout the ventral surface of the prothoracic ganglion, especially in the lateral areas. Current research is underway to identify, by immunohistochemistry, the specific biogenic amine(s) produced by the three to four large cells of the adult.

THE EFFECTS OF GHL ON THE EXPRESSION OF THE RAS PROTEIN IN NORMAL AND NEOPLASTIC CELLS. Christoffer Poulsen and Rosemary Barra, Dept. of Biol. Sci., Mary Washington College, Fredericksburg, VA 22401. Glycyl-histidyl-lysine (GHL) is a growth modulating factor that has been shown to have growth stimulatory effects on a number of mammalian cell lines. Previous studies in this laboratory have indicated that Morris Hepatoma 7777 Cells are stimulated by concentrations of GHL ranging from 1.0 to 5.0 ng/ml. In this study, the effects of GHL on the BRL-3A Buffalo Rat Liver cell line were investigated and it was found that these cells are not sensitive to GHL. In addition, studies were performed to determine the effects of GHL on the activity of the ras oncogene. Expression of the ras oncogene is associated with a wide variety of mammalian tumors. The ras gene encodes a 21 kd protein which was identified in cell extracts by SDS gel electrophoresis. The gels were analyzed using the Biorad Model 620 Densitometer and the 1D Analyst software. The results indicated that incubation of the Morris Hepatoma 7777 cells with 2.5 ng/ml of GHL significantly increased the amount of p21 protein produced by the cells.

THE EFFECTS OF SUCROSE AND NONNUTRITIVE SWEETNERS ON TRANSFORMED SCHWANN CELLS  
Alberta F. Springer, Berthie M. Labissiere, Sonya R. Moore, Dr. Phillip Archer\* and Dr. Regina Knight\*. Dept. of Biol., Va. State Univ., Petersburg, Va. 23806 A transformed Schwann Cell line from the sciatic nerve of neonatal rats and transfected with SV 40 T antigen were used as an *in vitro* system for assessing the effects of sucrose and nonnutritive sweetners as a possible indication of what occurs *in vivo*. Artificial sweetners have been known to promote differential effects on cell growth and morphology. Techniques of cell counting, cytological staining and protein determination were used to study cell proliferation, cell morphology, and protein changes when assayed at 24,48,72, and 96 hours after treatment with 10-2M and 10-3M concentrations of sucrose and the nonnutritive sweetner 'NutraSweet'. These studies have shown that over a period of time 'NutraSweet' and sucrose induces increases in protein synthesis and cell proliferation. These studies also indicate that sucrose and the nonnutritive sweetner NutraSweet have effects on Schwann cell morphology.

THE EFFECTS OF HYPERTHERMIA AND ADRIAMYCIN ON THE EXPRESSION OF STRESS PROTEINS. Raymond D. Stapleton and Rosemary Barra, Dept. of Biol. Sci., Mary Washington College, Fredericksburg, VA 22401. Hyperthermia is currently being used with either chemotherapy or radiation in the treatment of cancer. Although the biochemical responses to heat have not been fully elucidated, it is known that a specific group of proteins referred to as heat shock or stress proteins is induced. The major heat shock proteins are classified into four protein families including the hsp70 family, ranging from approximately 66 to 78 kD. Preliminary experiments in this laboratory indicated that the cytotoxic effect of the chemotherapeutic drug adriamycin is augmented by hyperthermia. Adriamycin is an intercalative antitumor drug that stimulates topoisomerase II mediated DNA strand breaks. In this study, the combined effects of adriamycin and hyperthermia on Morris hepatoma 7777 cells were investigated. In addition to the cytotoxic effects of the treatments, protein extracts were separated on 12% SDS polyacrylamide gels. The gels were analyzed by the Biorad Model 620 Densitometer and the ID Analyst program. The results indicate that treatment at 42°C for 30 minutes substantially increased the production of the hsp70 proteins and that adriamycin inhibited the hsp70 response.

INTERNAL HERMAPHRODITISM IN A WHITE-FOOTED MOUSE (PEROMYSCUS LEUCOPUS NOVEBORACENSIS). C. Richard Terman, Dept. of Biol., Col. William and Mary, Williamsburg, VA 23185. An adult White-footed mouse with male genitalia (penis with os penis) was captured on the Ecological Study Area of the Laboratory of Endocrinology and Population Ecology. Dissection and histological examination revealed an ovotestis and blind uterine horn on the right side and a testis and seminal vesicle on the left side. Two follicles, each containing an ovum, were present in the ovotestis. Spermatogonia and spermatocytes were present in the seminiferous tubules of both the ovotestis and testis. Hermaphroditism is rare in mammals and, to my knowledge, has never been reported in White-footed mice.

MID-SUMMER SUPPRESSION OF REPRODUCTION IN A WILD POPULATION OF WHITE-FOOTED MICE (PEROMYSCUS LEUCOPUS NOVEBORACENSIS) IS NOT PREVENTED BY SUPPLEMENTAL FOOD. C. Richard Terman, Dept. of Biol., Col. William and Mary, Williamsburg, VA 23185. A white-footed mouse population living on an 11 ha area has been studied monthly with 600 live traps since 1983. Trappability is greater than 90%. The proportion of adults which were reproductive was consistently and significantly lower during May, June and July than during February - April and August - October. The gonads and sex accessory glands were also significantly smaller during May - July. Surplus food which could not be hoarded was supplied in feeding stations on half the study area during 1991. Mice living on both the "food-added" and control portions of the study area exhibited similar reproductive inhibition during the same time of year as previously. These data indicate that factors other than food are responsible for the reproductive suppression observed. (Supported by a William and Mary Faculty Summer Research Grant and by the Thomas F. and Kate Miller Jeffress Memorial Trust).

**Biomedical and General Engineering (No Abstracts Submitted)****Botany**

RECENT GROWTH-TREND PATTERNS IN RED SPRUCE. H. S. Adams, D. S. Lancaster Cmnty. Col., Clifton Forge, VA 24422 and S. L. Stephenson, Dept. of Biology, Fairmont State Col., Fairmont, WV 26554. Growth-trend patterns exhibited by red spruce (*Picea rubens* Sarg.) since 1900 were analyzed using data obtained from increment cores collected at seven sites: two in western Virginia (mean elevation = 1125 m), two in southwestern Virginia (mean elevation = 1698 m), and three in eastern Tennessee/western North Carolina (mean elevation = 1833 m). Cores from each of the three localities were analyzed separately; cores also were examined by age class (<99 yr, 100-149 yr, and ≥150 yr). Comparison of average radial growth during each ten-year period (i.e., 1901-1910 through 1981-1990) revealed that growth-trend decline since 1960 is exhibited by trees at all three localities and in all three age classes. This trend is most pronounced for oldest trees and for trees in southwestern Virginia. The percentage of trees at all sites showing reduced growth in a given decade when compared with the preceding one was greatest (72.9) in the 1961-1970 decade. Our data show that, although growth-trend decline in red spruce has persisted since the 1961-1970 decade, the pattern has remained essentially the same during the two most recent decades.

PRELIMINARY CLASSIFICATION OF SINKHOLE POND VEGETATION IN THE SHENANDOAH VALLEY OF VIRGINIA. Nancy E. Van Alstine and Thomas J. Rawinski, Virginia Dept. of Conservation and Recreation, Div. of Natural Heritage. 1500 E. Main St., Suite 312, Richmond, Va. 23219. Shenandoah Valley sinkhole wetlands are rapidly being destroyed or degraded, and many associated rare plant species are at risk. More importantly, entire communities of life are being destroyed before they have even been described. The purpose of this paper is to classify the prevalent plant communities found in these wetlands and identify suspected environmental controlling factors. Presence/absence plant species data from 56 wetlands were analyzed using the Braun-Blanquet methodology. All but one of the wetlands had a seasonally flooded zone of vegetation classified as the *Quercus palustris* / *Panicum rigidulum-Panicum verrucosum* Alliance. Associations under this alliance included *Diospyros virginiana*/ *Andropogon virginicus-Fimbristylis autumnalis* and in disturbed wetlands, *Boltonia asteroides-Echinochloa crusgalli-Ambrosia artemisiifolia*. Some of the wetlands also had a vegetation type influenced by a semi-permanently flooded hydrologic regime; this vegetation was classified as the *Dulichium arundinaceum-Juncus canadensis-Proserpinaca palustris* Alliance. The *Scirpus torreyi-Eleocharis quadrangulata-Nuphar luteum* Community is the rarest vegetation type found in semipermanently flooded wetland zones.

ECOLOGICAL FACTORS INFLUENCING THE DISTRIBUTION OF *CAMPTOSORUS RHIZOPHYLLUS* (POLYPODIACEAE) IN THE WESTERN PIEDMONT OF VIRGINIA. Amy M. Anstey & Brian T. Hazlett, Dept. of Biol., Randolph-Macon Woman's Col., Lynchburg, VA 24503. Fifteen sites in eight counties south of the James River in the Virginia Piedmont were surveyed between September 1991 and April 1992 to determine the ecological factors influencing the distribution of *Camptosorus rhizophyllus*, walking fern. Factors studied included elevation, orientation, population size, stream size, stream proximity, slope class, rock type, associated vegetation, and soil pH. Based on data from these sites, we concluded that no sole factor determines this distribution. Instead, a combination of related environmental factors are needed to comprise suitable microhabitat. *Camptosorus rhizophyllus* populations predominantly occur on north-facing (54° to -31°) slopes which are undercut by a stream. The ferns are located on either the transporational midslope or colluvial footslope composed of metamorphic rock type (slate, schist or phyllite) usually of the Evington group under a dominant vegetation of either beech/oak or hemlock forests.

CRYOPRESERVATION OF EUKARYOTE ALGAE. Myron H. Beaty & Bruce C. Parker, Biol. Dept., Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. To increase the number of primarily eukaryote algae capable of recovery from cryopreservation, we subjected 365 culture strains from 13 of the ~19 algal classes to varying cryopreservation schemes. Preliminary tests led to an effective protocol which involved culturing the algae under low light ( $17-22 \text{ } \mu\text{E m}^{-2} \text{ s}^{-1}$ ) on semisolid (1% agar) media, transfer to liquid media with cryoprotectant 15-45 min prior to a controlled cooling regime at  $-10^\circ\text{C min}^{-1}$  to  $-40^\circ\text{C}$ , direct plunge into liquid nitrogen. By thawing after  $>1$  wk at  $-196^\circ\text{C}$  in a  $40^\circ\text{C}$  circulating water bath, cryopreserved samples were returned to 1% agar media and incubated as above. This protocol utilizing 5% DMSO as the cryoprotectant produced best recovery of 285 (78%) of the algal strains tested. Of the 57 successfully recovered genera, 29 were cryopreserved for the first time. Preliminary data suggest some relationships between systematic evolutionary lines, environmental preferences, cryoprotectants, and cryopreservability which could lead to a less empirical approach to cryopreservation and storage

NEWLY DISCOVERED POPULATIONS OF ISOTRIA MEDEOLOIDES (SMALL WHORLED POGONIA) IN VIRGINIA. Allen Belden, Jr. and Nancy E. Van Alstine, Va. Dept. of Conservation and Recreation, Div. of Natural Heritage, Richmond, Va. 23219. The authors spent a combined total of 34 days in 1991 searching for Isotria medeoloides at Marine Corps Base Quantico, located in Prince William, Stafford, and Fauquier counties. Before undertaking the search, information on known populations of Isotria medeoloides in Virginia was reviewed. Several potential habitat factors were isolated, involving aspect, inclination, soil type, physiographic province, physiognomy, and the presence of an indicator species. Three new populations were discovered, consisting of 33, 23, and four stems. The habitats of the new populations generally conform to those of other known Virginia populations, with several noteworthy exceptions.

VIABILITY OF STORED BRASSICA POLLEN. Catherine A. Boyd, M. H. Renfroe and J. Winstead, Dept. of Biol., James Madison Univ., Harrisonburg, VA 22807. Brassica is an agriculturally important plant genus. The family includes mustard and cabbage as two of its commercially valuable crops. The ability to store pollen may assist in breeding programs of important cultivars. Pollen from Brassica rapa anthers was collected dry, collected in water and dried, or whole anthers were collected. The pollen was stored at various temperatures: 24 C, 4 C, -20 C and -196 C. Pollen stored at -196 C was infiltrated with various cryoprotectants prior to freezing. Viability counts were taken periodically over 36 days. Pollen viability was assessed by staining with fluorescein diacetate and counts of viable pollen were taken using fluorescence microscopy. Pollen viability appears to show a decline over time relative to its collection method.

BRASSICA MICROGAMETOPHYTE MATURATION IN RELATION TO FLORAL BUD DEVELOPMENT. Thomas N. Buckley, Michael H. Renfroe and J. Winstead. Dept. of Biol., James Madison Univ., Harrisonburg, VA 22807. Microspores and pollen grains must be isolated at discrete stages of development to investigate microgametophyte maturation. Collection of developing microgametophytes at appropriate stages could be facilitated by the use of easily distinguishable morphological markers. Floral bud length, as well as sepal, petal and anther length were correlated with stages of microgametophyte development in Brassica rapa. Number and location of nuclei were used to determine developmental stages from microspore to gametophyte. During maturation of pollen grains, formation of the intine and exine was examined by scanning electron microscopy.

A PRELIMINARY REPORT ON THE DISTRIBUTION AND RARITY OF SPHAGNUM SPECIES IN VIRGINIA. Christopher A. Clampitt, Dept. of Conservation and Recreation, Division of Natural Heritage, 1500 E. Main St., Suite 312, Richmond, VA 23219 and Lewis E. Anderson\*, Department of Botany, Duke Univ., Durham, NC 27706. The genus Sphagnum is a distinctive, but poorly studied, taxon. Here we report on the results of field work and herbarium searches conducted over the past 4+ years. Twenty-nine Sphagnum species are known from Virginia, with collections from 74 cities and counties in the State. Twenty species have been documented to occur in the coastal plain, 18 in the mountains, and only 5 in the piedmont. Based on existing information, five species are uncommon in the U.S., 16 species are rare in Virginia, and 4 species are uncommon. Six more species are likely to occur, based on their distribution in adjacent states. Future work will undoubtedly prove that several species are more common than currently believed and also document species currently unknown from Virginia.

**Long-term *in vitro* viability of *Discula destructiva* conidia as determined by autofluorescence microscopy. J. B. Crozier, R. J. Stipes and H. L. Warren. Dept. Plant Pathol., Physiol. & Weed Sci., Virginia Tech, Blacksburg, VA 24061-0331.**

Viability of the propagules of a pathogen is crucial as a component of its life cycle, and of the disease cycle. Many variables in the disease biology of dogwood anthracnose might be satisfactorily explained if one knows the survival period of the conidia.

One indicator of spore death is cytoplasmic autofluorescence. Wu and Warren (*Mycologia* 76:1049-1058, 1984), who published the first report of natural autofluorescence in fungal propagules, found a high negative correlation between fluorescence and germination.

We examined the autofluorescence of conidia from a 5-month-old oatmeal agar culture of *Discula destructiva* (Va Tech Isolate DA-2 via Scott C. Redlin from *Cornus nuttallii*, western USA) incubated at 23C (=73.4F), and found that over 90% of the conidia were viable, i.e., did not fluoresce. We deduce that protective, anti-senescent properties reside in the mucilaginous matrix in which the conidia are borne; this matrix is common to many of the anthracnose taxa. These findings may suggest a characteristic of this fungus that enhances survival.

**COMPARISON OF PICOPLANKTON CONCENTRATIONS IN THE ELIZABETH RIVER, THE JAMES RIVER AND LOWER CHESAPEAKE BAY. Mary F. Hanover and Harold Marshall. Dept. Biological Sciences, Old Dominion University, Norfolk, Va. 23529-0266.**  
Autotrophic picoplankton abundance was noted over 25 months in the Elizabeth River, a polluted port river system. Seasonally, a unimodal pattern persisted, with a single peak development ( $2-5 \times 10^8$  cells/liter) during summer, decreasing into fall, with a winter low. Greater abundance was associated above the pycnocline in contrast to below this depth, and with the upstream station. However, picoplankters were less abundant in the Elizabeth River, in comparison to the James River and lower Chesapeake Bay, possibly indicating an influence of the lower water quality present in the Elizabeth River. (Supported by the Va. State Water Control Board and EPA.)

SEM IN THE PLANT ANATOMY TEACHING LABORATORY: STEM ANATOMY OF JUNCUS EFFUSUS. W. John Hayden, Dept. of Biol., Univ. of Richmond, Richmond, VA 23173. A laboratory assignment on stem structure of the soft rush, Juncus effusus, is described. Students prepared their own samples, which involved preservation in FAA, critical point drying in CO<sub>2</sub>, mounting on stubs with sticky tabs, and sputter coating with gold-palladium. By appointment each student had ca 30 minutes of hands-on operation of a Hitachi S-2300 SEM for observation of their samples. Polaroid electronmicrographs were made during each session; these were placed in plastic sleeves for study by all class members and served as data for individual reports. Juncus effusus stems provide diverse noteworthy features appropriate for student interpretation in the context of lecture topics: its division into cortex and pith is unusual for monocots; stellate pith parenchyma cells stand in stark contrast to theoretical models of parenchyma; pith and cortical cavities are interpretable as aerenchymatous ecological adaptations; presence of stomates and chlorenchyma emphasize the photosynthetic capacity of stems; proto- and metaxylem are clearly distinguishable. Finally, SEM images, because of their outstanding clarity and depth of field facilitate understanding of three dimensional aspects of plant structure.

BIOSTATIC INTRODUCTION OF THE GUS GENE INTO PINE EMBRYOS. Linda M. Hines and Michael H. Renfroe, Dept. of Biol., James Madison Univ., Harrisonburg, VA 22807. Genetic transformation of pines by traditional techniques such as *Agrobacterium*-mediated transformation has not been as successful as for dicots. One way to overcome the species host barrier is through the technique of microprojectile bombardment known as biolistics. A simple, inexpensive biostatic device was constructed that is capable of delivering DNA-coated tungsten microprojectiles into cells of loblolly pine (*Pinus taeda*) embryos. The DNA used was a plasmid containing the GUS ( $\beta$ -glucuronidase) gene as a marker for transformation. The operational parameters that were investigated included distance to target tissue, particle delivery pressure and GUS assay incubation conditions.

MICROPROPAGATION OF VIRGINIA ROUND-LEAF BIRCH. Joressia A. Jamison Michael H. Renfroe and J. Winstead, Dept. of Biol., James Madison Univ., Harrisonburg, VA 22807. A method of propagation through nodal culture was developed for Virginia round-leaf birch (*Betula uber* [Ashe] Fernald). Nodal cultures of Virginia round-leaf birch had the greatest shoot elongation on woody plant medium supplemented with BAP and GA. Shoot elongation was significantly greater when BAP was combined with GA over BAP used alone. In conjunction with propagation, anatomical changes in cuticle and stomata were examined at different stages of culture. Leaves taken from explants at time of transfer to soil exhibited the largest stomata and the greatest stomatal density. Stomata usually occurred on the abaxial surface of the leaf at all stages examined. On leaves from plants at transfer, stomata also occurred on the tip and margin of the teeth on the adaxial surface. These leaves also had the least amount of cuticle development and there was one layer of palisade parenchyma in cross section. Across all stages, cuticle development was thicker on the abaxial surface of the leaf than on the adaxial surface of the leaf.

**ANATOMY OF THE SEED SURFACE IN CHAMAESYCE: PRELIMINARY STUDIES OF THE MUCILAGINOUS LAYER.** Martha S. Jordan & W. John Hayden, Dept. of Biol., Univ. of Richmond, Richmond, VA 23173. Seeds of Chamaesyce (Euphorbiaceae) were studied for presence of mucilaginous testa. Samples were selected to represent all major systematic sections within the genus as classified by Boissier. Observations were made with a dissecting microscope following brief hydration of seeds; additional SEM observations of both intact and fractured dry seeds were made for selected species. Six (of eight) subsections routinely tested positively for seed mucilage; epidermal cells elongate greatly upon hydration into tubular extensions up to 0.5 mm long. Mucilage is generally absent in subsections Gymnadeniae and Sclerophyllae; absence of mucilage in these arborescent insular species is regarded as secondary loss from mucilaginous ancestors. Mucilage producing epidermis was found to be associated with subepidermal macrosclereids and, based on previous literature, these two cell layers are interpreted to develop from the epidermis of outer and inner integuments, respectively. Possible roles of seed mucilage include seed hydration and/or seed dispersal.

**ON THE TRAIL OF FERNALD III. THE REED MARSHES OF VIRGINIA BEACH AND CHESAPEAKE CITIES.** J. Christopher Ludwig, Department of Conservation and Recreation, Division of Natural Heritage, Main Street Station, 1500 E. Main Street, Suite 312, Richmond, Va. 23219. From 1933 to 1945, eminent Botanist, Merritt Lyndon Fernald explored the flora of Virginia's southeastern corner, looking for new, unusual, and rare plant species. During his explorations, he described the marsh flora of wind-tide systems in southeastern Virginia. Fernald's collection sites were revisited as well as additional marsh areas. Results of exploration into the reed marshes is presented emphasizing the occurrence and status of the wetland's rare plant species.

**SURVEY AND DOCUMENTATION OF THE VASCULAR PLANT SPECIES OF APPOMATTOX COURT HOUSE NATIONAL HISTORICAL PARK.** Anne Lund, Biol. Dept., Hampden-Sydney Col., Hampden-Sydney, VA 23943. Specimens of vascular plant species have been collected from different sites within Park boundaries. Communities which have been sampled include: grazed upland mixed woodlot, pasture, unfenced (but occasionally mowed) meadow, open and shaded roadsides, mixed woods' edge, and open river's edge. Information recorded in a database on identified species (over 90 to date) includes family, common name, habitat, collection site, and more. Degree and type of disturbance (relatively undisturbed woods to regularly plowed fields) is likely to continue in a reasonably predictable manner, making the Park an interesting research site for studying the botanical diversity of the Piedmont. The Park, while containing habitats representative of the central Piedmont but at the same time not subject to unpredictable land use, can be revisited and floral changes monitored over time.

**SEASONAL PICOPLANKTON CONCENTRATIONS IN THE JAMES, YORK AND RAPPAHANNOCK RIVERS.** Jeffrey Madden and Harold Marshall. Dept. Biological Sciences, Old Dominion University, Norfolk, Va. 23529-0266. Concentrations of autotrophic picoplankton were determined above and below the pycnocline in the tidal regions of these rivers over a 25 month period. The combined data sets indicated a winter low, followed by a gradual rise in abundance in late spring, with peak mean numbers ( $14 \times 10^8$  cells/liter) in summer, then a gradual decline in fall. The James and Rappahannock both exceeded the York in picoplankton abundance, but showed mixed results when compared to lower Chesapeake Bay sites. Counts were similar in 1990, but higher in the Bay during 1991. Greater abundance below the pycnocline was noted 1991 for the James River, with concentrations generally higher in surface waters. (Supported by the Va. State Water Control Board and EPA.)

THE PREPARATION OF A CHECKLIST OF THE CULTIVATED WOODY PLANTS OF THE SOUTHEASTERN UNITED STATES. Peter M. Mazzeo, Herbarium, U.S. National Arboretum, 3501 New York Avenue, NE, Washington, DC 20002. Herbarium specimens, photographs and field data collected at nearly 700 sites over the last 20 years have provided the basis for the first documented checklist of the cultivated woody plants grown in the gardens of the southeastern United States. More than 5,000 taxa have been documented.

In the process of this project, it was determined that some of the plant materials commonly available in the horticultural trade are mis-identified and sold under the wrong name. This annotated checklist, with synonymy, proper author citations and site locations for each taxon documented with herbarium voucher specimens, should help to alleviate some of these problems. This checklist should be an invaluable aid to botanists, horticulturalists, nurserymen, extension agents, gardeners, or anyone interested in the garden plants of the southeastern United States.

Publication by the U.S. National Arboretum, Agricultural Research Service, U.S.D.A., is expected in late 1992 or sometime in 1993.

POPULATION STRUCTURE AND DYNAMICS OF TWO MUSHROOM SPECIES ON A SOUTHERN APPALACIAN MOUNTAIN. John F. Murphy and Orson K. Miller, Dept. of Biol., Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. Basidiomycete fruiting occurrences on two spur ridges on Brush Mountain were mapped over a two year period. Marasmiellus praeacutus is a dominant litter decomposer on southwest slopes, and Collybia subnuda is dominant on northeast slopes. In vitro tests of somatic incompatibility demonstrate that populations of both species consist of large numbers of small, genetically distinct individuals. Preliminary tests indicate a low mating allele diversity within the populations examined.

IN VITRO GERMINATION OF BRASSICA POLLEN. Mark A. Newsome and Michael H. Renfroe, Dept. of Biol., James Madison Univ., Harrisonburg, VA 22807. Investigation of chemical constituents that initiate pollen tube development is necessary for understanding the physiology of events that occur following pollination. The *Brassica* genus is economically and agronomically important. Determination of a successful in vitro pollen germination medium may provide insights to the in vivo requirements for successful pollination. Many successful in vitro germination media have been reported for binucleated pollen species. However, in vitro germination of trinucleated pollen has been less successful. *Brassica* pollen is trinucleate when shed and few germination media have been reported. Various liquid and semi-solid, chemically defined media were tested for pollen germination. Experimental data were collected over a 24 hour incubation period. A comparison of carbohydrates in the media revealed that sucrose rather than raffinose or glucose was most effective for germination. Specifically, 20% sucrose provided the highest percentage germination.

SEASONAL PICOPLANKTON CONCENTRATIONS IN THE LOWER CHESAPEAKE BAY. Karen Phillips and Harold Marshall. Dept. Biological Sciences, Old Dominion Univ., Norfolk, Va. 23529-0266. Results of a 25 month study of autotrophic pico-plankton at stations in the lower Chesapeake Bay indicated a single summer concentration peak occurred during each year, with the major development in June, July and August. Lowest abundance occurred in winter. Mean summer surface concentrations were  $6-7 \times 10^8$  cells/liter, with mean concentrations below the pycnocline  $2 \times 10^8$  cells/liter. There was a tendency for higher concentrations along the western margin of the lower Bay in contrast to the eastern region. Inter annual differences in abundance were noted between the two years. (Supported by the Va. State Water Control Board and EPA.)

CONCEPTS OF THE BRAUN-BLANQUET APPROACH TO COMMUNITY CLASSIFICATION APPLIED IN VIRGINIA: CLASSES OF INDIGENOUS VEGETATION. Thomas J. Rawinski, Va. Dept. of Conservation and Recreation, Div. of Natural Heritage, Main Street Station, 1500 E. Main St., Suite 312, Richmond, Va. 23219. Community classification, inventory, and research are absolutely essential if we are to protect a full measure of biological diversity and effectively manage natural areas into the future. Toward this goal, a classification of Virginia's vegetated communities was recently developed. The classification was modelled after the Braun-Blanquet approach, employing a hierarchy and diagnostic plant taxa. Conditional character-species were used within dichotomous keys to differentiate community classes; these plants represent a broader application of the differential-species concept. The Virginia classification includes 43 classes, and in a test case, data sets from 69 plots of forest vegetation were easily classified. This exercise, in turn, greatly facilitated a more detailed classification of distinct associations through the use of a vegetation synthesis table. The new classification permits consistent nomenclature of broad vegetation types across Virginia. It will likely improve through continuous use and refinement.

ANATOMY OF ROOT SHOOT TRANSITION REGION IN AUSTRIAN PINE. Michael H. Renfroe, Dept. of Biol., James Madison Univ., Harrisonburg, VA 22807. As pines develop from embryos to seedlings, differentiation of the procambium gives rise to two distinct anatomies in the shoot and the root of the plant. Somewhere along the length of the hypocotyl, a transition in tissue arrangement must occur to align the vascular tissues of the two regions. In Austrian pine, the transition region occurs in the uppermost few millimeters of the hypocotyl, immediately below the cotyledonary node. For most of the length of the hypocotyl, the xylem arrangement was exarch tetrarch, although in some seedlings, it was pentarch or hexarch. A single resin duct was located external to each xylem pole. Toward the acropetal end of the hypocotyl, there was progressive lateral differentiation of metaxylem until xylem patches were no longer discrete, but formed a metaxylem ring central to both the resin ducts and metaphloem. Proximally along the cotyledons and basipetally into the hypocotyl, xylem of the cotyledons was continuous with this vascular ring.

MANAGEMENT OF DOGWOOD ANTHRACNOSE WITH FUNGICIDES. F.D. Smith, USDA Forest Service, Otto, NC 28763; J.B. Crozier, and R.J. Stipes, Dept. of Plant Pathology, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. Dogwood Anthracnose is caused by the fungus *Discula destructiva*. This exotic pathogen has caused severe mortality on flowering dogwood (*Cornus florida*), primarily on trees in the mountainous counties of Va. The sensitivity of three isolates of *D. destructiva* to 10 fungicides was tested on potato-dextrose-yeast agar. Four triazole fungicides were extremely active *in vitro*. Average ED<sub>50</sub> values were 0.00053, 0.0021, 0.020, and 0.043 µg/ml for propiconazole (Banner), fenbuconazole (RH-7592), tebuconazole (Lynx), and myclobutanil (RH-3866), respectively. ED<sub>50</sub> values for other fungicides were 0.011, 0.034, 0.048, 0.81, 1.3, and 2.9 µg/ml for benomyl (Benlate), fluazinam (ASC-66825), CGA-173506 (n.a.), chlorothalonil (Daconil), iprodione (Chipco 26019), and triforine (Funginex), respectively. A field trial using potted dogwood seedlings was conducted in western N.C. during 1991. Healthy seedlings were placed in the forest and exposed to naturally occurring inoculum. Four applications of fungicides were applied at recommended rates. The final disease rating of leaf-area infection was made on 10 Sep. ASC-66825 50WP (8 oz/100 gal.), Lynx 2F (3 fl. oz), Daconil 4.17F (32 fl. oz), and Banner 1.1 E (8 fl. oz) were the most effective treatments as they significantly ( $P \leq 0.05$ ) suppressed disease by 75, 71, 57, and 53%, respectively. Daconil is available for control of dogwood anthracnose, and Banner is expected to be marketed soon.

RELATIONSHIP OF WATER-DROPLET CONTACT ANGLE ON LEAVES OF *CORNUS* spp. TO SUSCEPTIBILITY OF DOGWOOD ANTHRACNOSE DEVELOPMENT. F.D. Smith, USDA Forest Service, Otto, NC 28763; R.J. Stipes, Dept. of Plant Pathology, M. Babai\*, Dept. of Chemistry, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. The waxy leaf cuticle on *Cornus* spp. may play a role in governing the susceptibility to *Discula destructiva*, causal agent of dogwood anthracnose. A contact-angle goniometer (model 100-00, Ramé Hart Inc., N.J.) was used to measure the water-droplet contact angle formed by a 5- $\mu$ L droplet of distilled water placed on leaf samples from five dogwood species: flowering (*C. florida*), gray (*C. racemosa*), Japanese (*C. kousa*), silky (*C. obliqua*), and red-osier (*C. stolonifera*). A 7 x 7 mm area of leaf tissue was obtained from 1-yr old, greenhouse-grown dogwood seedlings. The water-contact angle was smallest on leaves of flowering and gray dogwood, with an average angle of 91.4° and 92.0°, respectively. Average contact angles on red-osier and Japanese dogwood were significantly ( $P \leq 0.05$ ) larger, at 99.7° and 100.8°, respectively. Silky dogwood leaves had the largest average contact angle of 110.8°, which was significantly larger than other averages. Based on the small water-droplet contact angle, the leaf surface of flowering dogwood appeared to be the least hydrophobic of the five species. The high level of susceptibility of flowering dogwood to infection by *D. destructiva* may be due in part to the ability of water to cling to leaves after precipitation, providing conditions favorable for infection.

MANIPULATIVE FOCUS IN EXOTIC PLANT MANAGEMENT: AUTECOLOGY VS. SYNECOLOGY. L. K. Thomas, Jr.\*, Research Biologist, National Park Service, National Capital Region, Washington, D.C. 20242. After removing kudzu (*Pueraria lobata*) from dominance on 57 sites/colonies through a variety of methods, almost half the sites/colonies subsequently became dominated by other exotic plant species. Those sites/colonies dominated by native species after kudzu removal were associated with such forest influences as native dominants, density dependent environment, multiple physiological ages, and community closer to climax (compared to exotic plant dominated areas). By focusing on the autecology of the kudzu, the kudzu as a population was controlled, but other exotic species populations were not. Only when the essential synecological factors of populations and communities were in place, were exotic species generally controlled. Present methods of control emphasize population control and this is done by manipulating the autecology of the target species. To control all the exotic species at the site the standard of success must no longer be judged by the condition of the population, but the standard must be the community or ecosystem. To manipulate these, synecological principles must be used. The basic result must be a restoration of the site so it is dominated by the characteristics that discourage exotic species.

Scanning electron microscopy of upper (adaxial) leaf surfaces of *C. florida*, *C. kousa*, *C. kousa* var. *angustata*, *C. obliqua*, *C. racemosa* and *C. stolonifera*.

Kyle T. Thornham\*, R. J. Stipes, and R. L. Grayson, Dept. of Plant Pathology, Virginia Tech, Blacksburg, VA 24061-0331

Leaf surfaces of 6-wk-old greenhouse flowering (*Cornus florida*), gray (*C. racemosa*), silky (*C. obliqua*), kousa (*C. kousa*) and red osier (*C. stolonifera*) dogwoods were observed by scanning electron microscopy. Trichome size, shape and number per unit area of leaf surface differed among species. Numbers of trichomes counted in the 50X magnification field were 40 for *C. florida*, 37 for *C. kousa*, 25.6 for *C. stolonifera*, 17.6 for *C. racemosa* and 12.3 for *C. obliqua*. Attempts were made to associate trichome density with susceptibility/resistance to dogwood anthracnose.

(We express appreciation to Dr. Theodore R. Dudley, U. S. National Arboretum, for the specimen of *C. kousa* var. *angustata*).

**Effect of acid deposition on trichome morphology and dogwood anthracnose biology.**

Kyle T. Thornham, R. Jay Stipes and Randolph L. Grayson. Dept. Plant Pathol. Physiol., & Weed Sci., Virginia Tech, Blacksburg, VA 24061-0331.

Dogwood anthracnose, caused by *Discula destructiva*, is another new catastrophic tree disease that has ravaged natural populations of the flowering dogwood (*Cornus florida*) in the Appalachians over the past 15 years, and the epidemic is prognosticated to continue. Since acid deposition has been linked experimentally with disease induction, and since the disease incidence and severity are more pronounced at higher elevations where lower pH precipitation events occur, we investigated the effect of acidic foliar sprays on morphologic changes in the foliar cuticle and trichomes, the initial sites of infection and foci of *Discula* sporulation. Individual 3-mo-old greenhouse-grown plants were sprayed daily with HCl-acidified distilled water at pHs of 1-7 for 7 days. Cork borer disk samples were harvested prior to treatment, and daily thereafter for 7 days. Samples were viewed with an SEM. Highly acidic (pHs 1-4) depositions at the first day onward desiccated trichomes to their bases, while pH 5 was transitional causing some trichome deterioration over time, and exposures at pHs 6 and 7 produced no observable abnormal effects. This trichome shrinkage and accompanying tissues damage might facilitate nutrient metabolite leakage and entry for the fungal hyphae at the trichome base where *Discula* infection might occur and sporulation is profuse.

**GENETIC FRUIT POLYMORPHISM IN VALERIANELLA RADIATA (L.) DUFR.**

(VALERIANACEAE). Donna M. E. Ware, Dept. of Biol., Col. of William and Mary, Williamsburg, Va. 23185. Genetic polymorphisms for fruit shape were previously demonstrated to occur in *Valerianella ozarkana* (2 morphs), *V. longiflora* (2 morphs), *V. nuttallii* (2 morphs), and *V. umbilicata* (3 morphs), all of which are showy-flowered species. Morphology and distribution indicated that the small-flowered, largely inbreeding *V. radiata* was also polymorphic for fruit shape. To test this, large numbers of fruits were planted from a colony in Monroe, La., for which a systematic sample (94 plants) contained 25% f. *radiata*, 48% f. *fernaldii*, 17% f. *demareei*, 6% of an undescribed fruit type, and 3% of two kinds of intermediates. Progeny segregated as follows: *radiata* to *fernaldii* = 1 (2%); *demareei* to *fernaldii* = 1 (0.9%); *fernaldii* to *demareei* = 3 (4%). Sowing of fruits from the latter three *demareei*-fruited plants yielded 15 (38%) *fernaldii*-fruited plants. These tests indicate that there are at least three genetic fruit morphs in *V. radiata*.

**SUBSTRATE TOLERANCE AND DISTRIBUTION IN ROCK OUTCROP ENDEMICS:**

**DIAMORPHA, SEDUM, AND CYPERUS.** Stewart Ware, Dept. of Biol., Coll. of William and Mary, Williamsburg, VA 23185. *Sedum nuttalianum* of the Ozarks and *Diamorpha cymosa* (= *S. smallii*) and *Cyperus granitophilus* of the Piedmont are found in very shallow soil of granite and sandstone outcrops. In contrast, *S. pulchellum* and *C. aristatus* of the same habitats occur on limestone as well. Populations of each species were grown on its own soil and an alien soil, and success measured by total growth. *Sedum nuttalianum*, *D. cymosa*, and *C. granitophilus* grew well on granite and sandstone, but not on limestone. *Sedum pulchellum*, even from sandstone, grew well only on limestone. *Cyperus aristatus* from limestone grew poorly on non-limestone soils, especially serpentine. Populations from sandstone grew best on sandstone and granite but still flowered and fruited on limestone soil. The first three species would not be expected to colonize limestone; *C. aristatus* could colonize any outcrop. *Sedum pulchellum* should not colonize sandstone, but has!

ECOLOGICAL EXPERIMENTS ON DIATOM COLONIZATION IN A SMALL STREAM. Susanne Wendker. Dept. Biological Sciences, Old Dominion Univ., Norfolk, Va. 23529-0266. In a first order stream (Breitenback, Hesse, Germany) colonization experiments were carried out to study diatom reactions to different current velocities in experimental channels placed in the stream. Four different current velocities were adjusted to 0.5, 20, 30, and 50 cm.s<sup>-1</sup>. Microscope slides were used as substrata for diatom colonization with grazers not excluded. A total of 39 taxa were present, with 13 having relative abundances of >=5%. From these 13 taxa, 10 showed reactions to the different current velocities. Similarity indices and species richness were also present. Microscope slides were also exposed at two stream sites that differed in their physical and chemical parameters. After six weeks, the slides were transferred, and changes in the diatom communities were then studied after 3 days, 1 week, and 1 month. Reactions of the communities to these conditions were presented.

PHYTOPLANKTON RELATIONSHIPS DURING A PTYCHODISCUS BREVIS BLOOM. Traycie L. West, H.G. Marshall, and P.A. Tester. Dept. of Biological Sciences, Old Dominion University, Norfolk, Va. 23529-0266. In late October 1987, a red tide bloom event was reported off the North Carolina Coast. *Ptychodiscus brevis* was identified as the causative species. This bloom event persisted until late February, resulting in economic losses to the local community in excess of \$24 million. The relationships between this toxic dinoflagellate and phytoplankton community components are currently being investigated. Results indicate diatom, chlorophyte, cryptomonad, and dinoflagellate components have modest increases in abundance accompanying bloom concentrations of *P. brevis*. No other algal component shared bloom concentrations. However, cyanobacteria decreased in abundance in association with *P. brevis*. Coccolithophores and silicoflagellates were not abundant in any sample. The picoplankton concentrations did not appear to be related to *P. brevis* abundances.

HURRICANES AND EXOTICS: DISTURBANCE AND THE ESTABLISHMENT OF PAULOWNIA TOMENTOSA IN A PIEDMONT RIPARIAN FOREST. Charles E. Williams, The Nature Conservancy, 1110 Rose Hill Dr., Suite 200, Charlottesville, VA 22903. The empress tree, *Paulownia tomentosa* (Thunb.) Steud., is native to eastern Asia. Introduced to cultivation as a fast-growing ornamental and lumber tree, *P. tomentosa* is now widely naturalized in portions of the eastern United States. Little is known of the ecology of the exotic *P. tomentosa* in native forests of this region. I examined the age structure and importance of *P. tomentosa* in a central Virginia riparian forest. The age structure of *P. tomentosa* was unimodal with a peak in the 18-20 year age classes, suggesting a major recruitment pulse in the early 1970s coincident with the passage of Hurricane Camille (August 1969). Trees ranged from 6-30 years of age (mean age = 17.1 years). *P. tomentosa* was least in importance (importance value = 15.1) among the four dominant forest trees in the study site (*Liriodendron tulipifera*, IV = 30.1; *Betula lenta*, IV = 28.5; *Platanus occidentalis*, IV = 16.0). However, *P. tomentosa* was second only to *L. tulipifera* in relative basal area, reflecting the relatively large size and quick growth of *P. tomentosa* compared to the co-occurring native tree species. Diameter distributions for all major tree species except *P. tomentosa* followed a concave pattern, suggestive of increasing or self-maintaining populations. The diameter distribution for *P. tomentosa* was convex, indicative of a reproductively stagnant population. Overall, the data suggest that *P. tomentosa* invaded the watershed immediately after the devastation of Hurricane Camille when conditions favored its establishment. Unlike many exotics in eastern forests, *P. tomentosa* behaves much as it does in the deciduous mesophytic forests of eastern Asia, producing small, short-lived populations following large-scale disturbance.

THE DISTRIBUTION OF SWEETGUM (LIQUIDAMBAR STYRACIFLUA L.) IN THE VIRGINIA PIEDMONT. Robert A. S. Wright, Consulting Biologist, 5204 Riverside Drive, Richmond, Virginia 23225. One of the most interesting phytogeographical phenomena in the Virginia flora is the "Southwestern-Virginia Gap" whereby many native austral species common to the coastal plain and outer piedmont become increasingly localized and gradually disappear the further west one searches. Sweetgum has been used for many years as the classic example of a native Virginia species manifesting this intriguing distributional pattern, but never has its western-most piedmont stations been documented by herbarium specimens and exhaustive field work. Such an undertaking has been ongoing since 1985, and preliminary analyses confirm that the gap is very real and is readily observable in the field near or at sweetgum's present piedmont distributional limit. Adventive populations beyond the recognized "natural" boundary have been documented and the evidence shows that sweetgum is limited along the James, Rappahannock and Potomac Rivers along its western boundary in northern and central Virginia. Further south, there exists a gradient that is correlated to a Triassic soil type. All distributional data to date is presented and explanations/interpretations are discussed.

## Chemistry

PHOTOCHEMISTRY OF COMPLEXES: DO ORIENTATION AND PROXIMITY MATTER? Samuel A. Abrash\*, Jennifer J. Brown\*, Michael T. McMahon\*, Dora M. Paolucci\*, and Robert W. Zehner\*, Dept. of Chem., Univ. of Richmond, Richmond, VA, 23173. Advances in the understanding of the photochemistry of isolated molecules have proceeded to the point at which fruitful examination of the dynamics of bimolecular reactions is now possible. Weakly bound complexes are excellent model systems for studying the dynamics of reactions following the initial collision. By studying the photochemistry of matrix isolated T shaped complexes of HBr and HI with acetylene and comparing the results with those of uncomplexed systems, conclusions can be drawn about the effect of proximity and orientation on the photochemistry. Attention is focussed on the differences in the photochemistry of HBr-acetylene complexes and vinyl bromide, and on the photolysis wavelength dependence of the product distribution of HI-acetylene complexes.

HOMOPOLYMERIZATION OF  $\beta$ -BENZYL-L-ASPARTATE AND  $\gamma$ -BENZYL-L-GLUTAMATE NCA'S. S.Antoun, Jian-Zhong Yang, and Raphael Ottenbrite, Dept. of Chem., Va Commonwealth Univ., Richmond, Va. 23284. A series of polymerizations of  $\alpha$ -amino acid-N-carboxyanhydrides (NCA's) of  $\beta$ - and  $\gamma$ -benzyl esters of L-aspartic and L-glutamic acids using different initiators such as benzyl amine and triethylamine were carried out. Oligopeptides were prepared with some molecular weight control from primary amine initiated polymerizations. Higher molecular weight polypeptides were also obtained by using tertiary amine as an initiator. A new initiation by methyl ester of  $\alpha$ -amino acids was also attempted, from which 'pure' oligopeptides were synthesized. The polymers obtained were characterized by NMR, FT-IR, and GPC.

KINETIC CHARACTERIZATION OF MULTIPLE FORMS OF THE GUANINE-7-METHYLTRANSFERASE. Z. Batrouni and T.O. Sitz, Dept. of Biochem., Virginia Tech, Blacksburg, VA 24061. The methylation of the guanine-7-position in the cap structure at the 5'-terminus of eucaryotic mRNAs is required for proper processing and translation. During the purification of the nuclear guanine-7-methyltransferase from tumor cells, three peaks of enzyme activity using the mRNA analog (GpppGpN---pN) as the RNA substrate were observed. Why are three enzyme forms found? Does this represent three different enzymes or charge microheterogeneity of a single enzyme? The enzyme kinetic parameters of the three peaks of activity were determined. The Km values for the substrate S-adenosylmethionine were found to be the same and similar to previously determined values (about 4.5uM). The Km values for the RNA substrate were also similar but the data had greater variation due to heterogeneity of chain length of the RNA. These data together with the following abstract (R. Kerns and T.O. Sitz) suggest that the multiple peaks result from variation in charge that does not effect the activity of the enzyme. Therefore, the charge heterogeneity probably is not physiologically significant.

CRITICAL THINKING: PREDICTOR OF SUCCESS IN CHEMISTRY? Lillian D. Berg, Chemistry Department, Northern Virginia Community College, Annandale, VA 22003. The Watson-Glaser Critical Thinking test has been administered to two levels of chemistry classes: General Chemistry (GOB) CHM 101 which has not chemistry prerequisites and to Organic Chemistry CHM 241 which has as a prerequisite College Chemistry CHM 111-112. Scores on the Watson-Glaser test correlated with grades received for the course i.e., LESS THAN 40/80 was a good predictor of D, F, or W grade, WHEREAS 60/80 score was a good predictor of an A or B grade. There was also correlation between the D, F, W grade and lack of English language facility by non-native students in the Organic Chemistry class. Lack of basic algebra was also found to be a strong factor in D,F,W grades in CHM 101. A Critical Thinking test appears to be a good indicator of students who are AT RISK for mastery of these chemistry courses.

ORGANIC STRUCTURE ELUCIDATION WORKSHOP FOR HIGH SCHOOL TEACHERS AND STUDENTS  
Stuart C. Clough, Department of Chemistry, University of Richmond, Virginia 23173.

This presentation will describe an intensive 2 day workshop intended to upgrade a high school teacher's interest and expertise in instrumental analysis (IR, NMR, UV, MASS SPEC, CHROMATOGRAPHY). The workshop provides enrichment and excitement for a selected group of high school students thereby ultimately encouraging an interest in science in the minds of students in the secondary schools. The workshop combines lectures with hands on problem solving in the laboratories.

#### PROJECT ACAC REVISITED

Melissa Crouch, Karen Scott\*, Brett Wilkinson\*, and T.C. DeVore  
Dept. of Chem., James Madison University, Harrisonburg, VA 22807

The goal of Project ACAC was to incorporate the synthesis and characterization of an organo-metallic compound into the introductory chemistry laboratory. Procedures which produce the 2,4 pentanedionato complexes of chromium (III), aluminum (III), or copper (II) and substituted ACAC's of nickel (II) in approximately one hour have been developed. FTIR, UV-visible spectroscopy, and GC-mass spectra are used to characterize these metal ACAC's which provides an introduction of these techniques to freshman chemistry majors. FTIR evolved gas analysis and weight loss measurements can be used to further characterize the nickel complexes.

PREPARATION AND CHARACTERIZATION OF POLY(MALEIC ANHYDRIDE-CO-2-CYCLOHEXYL-1,3-DIOXEPIN-5-ENE). Jian-Ling Ding and Raphael M. Ottenbrite, Chemistry Department, Virginia Commonwealth University, Richmond, Va. 23284. A polymer-polymer grafting method was used to prepare poly(maleic anhydride-co-2-cyclohexyl-1,3-dioxepin-5-ene) (MA-CDA) with molecular weight of 20,000 or higher. The MA-CDA polymer was synthesized through free radical polymerization. This polymer was modified by amidation with grafting ethanolamine. The amide modified MA-CDA, which has free hydroxyl groups pendent on the chain, was grafted onto anhydride groups of MA-CDA polymer through ester bond formation. The molecular weight of products was controlled by varying the molar ratios of modified polymer to the original polymer. The resultant MA-CDAs were characterized by viscometry and gel permeation chromatography.

**SYNTHESIS, STRUCTURAL AND CHARGE TRANSFER PROPERTIES OF NEW ClRe( $\alpha,\alpha'$ -DIIMINE) COMPLEXES** Raymond N. Dominey, Michael Rooney, John Hubbard, Jennifer Dunham, and Rene Kanders, Department of Chemistry, University of Richmond, Richmond, VA 23173.

The complexes  $\text{ClRe}(\text{CO})_3\text{L}$  [ $\text{L}$  = "open  $\alpha,\alpha'$ -diimine ligands" =  $\text{N}-(2\text{-pyridinylmethylene})\text{-phenylamine}$  (2-PP),  $\text{N}-(2\text{-pyridinylmethylene})\text{-cyclohexylamine}$  (2-PC), and methylated analogues of 2-PP] have been prepared and characterized both structurally and photophysically. Their absorption spectra at 298 K, emission spectra and luminescence lifetimes at 77 K, and redox potentials will be reported. The absorption and emission are assigned to MLCT transitions. Increased polarity of the solvent causes a blue shift in the MLCT absorption. Correlations between the electrochemical properties and both the absorption and emission energies will also be discussed. Based on preliminary results from extended Huckel MO calculations, methylated analogues of the above complexes have been made and studied. Correlation of experimental results with computational predictions will be discussed.

MOLECULAR DYNAMICS SIMULATION OF A SIMPLE MODEL OF PROTEIN FOLDING. Rachael M. Easton, Cindy Heffern, and Steven G. Desjardins, Dept. of Chem., Washington and Lee Univ., Lexington, VA 24450. Several simplified models of the small protein bovine pancreatic trypsin inhibitor (BPTI) have been studied using molecular dynamics on a microcomputer. These models differ primarily in the number of sites (repulsive cores) used to represent each amino acid as well as geometric constraints bond length and angle. These models range from one to four sites per amino acid. The initial collapse into a globular shape is considered in the presence of a mean field aqueous solvent. The stability of the crystallographic structure with the four site model is also discussed.

TRANSITION METAL COMPLEXES OF SILYL LIGANDS. Emma W. Goldman, Colleen Kelley, Michael Terry, and Eric Flickinger, Department of Chemistry, University of Richmond, VA 23173. Bonding of a transition metal to an organosilicon compound affects the reactivity at silicon. Transition metals have also been shown to stabilize reactive silyl intermediates. We have synthesized two series of compounds to study these effects. The first series is of the type  $(C_5H_5)M(CO)_2SiR_2X$  (where M = Fe, Mo, W; X = H, Cl, F, OR') and have the silicon directly bonded to the metal. The second series consists of silacyclopentadienyl complexes where the metal is pi bonded to the ring.

OXIDATIVE INCORPORATION OF IRON INTO APOFERRITIN PROMOTED BY XANTHINE OXIDASE. Alice Hall-Sizemore, C. Marks and R. Topham, Department of Chemistry, University of Richmond, Virginia 23173.

Ferritin is the iron storage protein utilized by most living cells. Iron is accepted by the protein shell in the ferrous form and is stored in the core as microcrystalline ferric oxide. A ferroxidase activity is required for core formation to proceed at a significant rate. The apoferritin protein shell exhibits some ferroxidase activity. In recent years it has been demonstrated that xanthine oxidase is a potent ferroxidase that can promote the oxidative incorporation of iron into apotransferrin. In these studies, we demonstrate that xanthine oxidase can markedly accelerate the oxidative incorporation of iron apoferritin as well. Kinetic,  $^{59}Fe$ -labeling, and purine specificity studies will be discussed. This work was supported by NIH Grant DK 38318.

A NOVEL KINETIC DETECTION METHOD FOR THE QUANTITATION OF ENZYMES ON ELECTROPHORETIC MEDIA. Robin S. Hampton and Sarah C. Rutan, Dept. of Chemistry, Va. Commonwealth Univ., Richmond, Va. 23284. We have combined fluorescence, charge coupled device imaging, and kinetic data analysis to form a new analytical method which allows the quantification of unresolved bands on electrophoretic media. The isozymes of alkaline phosphatase (ALP) were used in the initial characterization of this technique. The detection of the isozymes is achieved by reacting them with a substrate that produces a fluorescent product. By observing the rate of this product formation, the activity of the isozymes can be calculated. If two isozymes are poorly resolved on the electrophoresis media then the addition of a denaturing agent can be used to cause differential deactivation of the isozymes. The denaturation of each isozyme proceeds at a distinct rate which in turn affects the overall rate of fluorescent product formation. In this way overlapped bands can be distinguished and quantified. Results for bovine ALP isozymes will be presented.

CHARACTERIZATION OF SOLVATED LIQUID CHROMATOGRAPHIC STATIONARY PHASES USING POLARITY-SENSITIVE DYES. Robin Helburn, Dewey Mitchem\* and Sarah Rutan\*; Dept. of Chemistry, Box 2006 Virginia Commonwealth University, Richmond VA 23284-2006. The study of the molecular mechanisms of solute separation in liquid chromatography (LC) is presently an active area of research. The interface between mobile and stationary phases is a complex environment whose nature and properties are not precisely known. In this work, a series of solvatochromic dyes have been used to spectroscopically probe the solvated surfaces of silica and  $C_{18}$  bonded silica as a function of changing mobile phase conditions. The solvatochromic parameters  $E_t$  and  $\pi^*$  have been determined for these systems. This presentation will focus on the properties of solvatochromic dyes, and on how these compounds can be used as polarity indicators in the characterization of heterogeneous systems. (Supported By the National Science Foundation)

**Characterization and Durability of Adhesively-bonded Composites.** Brenda L. Holmes and John G. Dillard, Department of Chemistry, Center for Adhesive and Sealant Science, Virginia Tech, Blacksburg, VA 24061-0212. The durability of adhesively bonded thermoplastic-based composites has been investigated. Time to failure and mode of failure have been determined with respect to the surface chemistry of composite adherends and the chemical nature of the test environment. The nature of the composite surface preparation and the environment of the durability experiments were selected so that the chemical nature of interactions (acid/base) at the adherend/adhesive interface could be investigated. The matrix resin in the composites included polyolefin and polyester materials, and the surface chemistry of the composites was altered by chemical and abrasive mechanical treatments before adhesive bonding. Surface analysis results indicate that for bonded-as-received samples tested above ammonium hydroxide, failure occurs at the adhesive-composite interface. On the other hand, for bonded-as-received samples exposed to acetic acid vapor failure takes place via near-surface delamination of the composite.

**CHARACTERIZATION OF MULTIPLE FORMS OF THE GUANINE-7-METHYLTRANSFERASE.** R. T. Kerns and T.O. Sitz, Dept. of Biochem., Virginia Tech, Blacksburg, VA 24061. The guanine-7-methyltransferase that methylates the cap structure in mRNA is very important in gene expression. If a mRNA is not methylated it is ineffectively processed and translated. During the purification of this enzyme three peaks of methyltransferase activity, using the GpppGpN---pN RNA substrate, were eluted from the Mono-Q column. Are these three activity peaks the guanine-7-methyltransferase or other types of methyltransferases (such as 2'-O-methyltransferase or other internal base methyltransferases)? The RNA products produced by the three peaks of enzyme activity were isolated and characterized by base hydrolysis and DEAE-Sephadex column chromatography. The methylated product in all three samples was found to be G<sup>m</sup>pppGp; thus, the three peaks of activity eluting from the Mono-Q column were the guanine-7-methyltransferase.

**MICELLAR EFFECTS ON ELECTROCHEMISTRY OF HYDROPHOBIC METAL COMPLEXES.** Peter King and Keith Davies, Chemistry Dept., George Mason Univ., Fairfax, Va. 22030. Cyclic voltammetry has been used to examine the redox behavior of cobalt phenanthroline and terpyridine complexes,  $\text{CoL}_3^{3+/2+}$  ( $L = \text{phen}$ , 5-CI-phen, 5-Me-phen, 5,6-Me<sub>2</sub>-phen), and  $\text{CoL}_2^{3+/2+}$  ( $L = \text{terpy}$ ) in SDS and Triton X-100 surfactant solutions. Shifts in half-wave potentials in SDS to more positive potentials, accompanied by reduction in peak currents, are interpreted in terms of net stabilization of reduced species through hydrophobic association with the micellar sub-phases. Much smaller changes in Triton X-100 indicate weak association with non-charged micelles. The uncharged  $\text{Co}(\text{5-SO}_3^-\text{-phen})_3$  complex does not appear to associate with anionic (SDS) or cationic (CTAB) micelles, but does so with non-ionic Triton X-100. Homogeneous electron transfer rate constants have also been measured by stopped-flow spectrophotometry for  $\text{Co}(\text{terpy})_2^{2+}$  reduction of cobalt(III) phenanthroline complexes in the micellar solutions.

**SYNTHESSES OF SUBSTITUTED BENZO-15-CROWN-5 ETHERS.** Monica H. Luke, J. Thompson Strode, Susan E. Thomas, D. S. Amenta and J. A. Mosbo, Dept. of Chem., James Madison Univ., Harrisonburg, Va. 22807. The goal of the research was to prepare transition metal complexes bearing crown ether ligands in the hope that interactions of alkali metal cations with the complexes would affect their properties. Consequently, the syntheses of 4'-YCH<sub>2</sub>benzo-15-crown-5, where Y is a good leaving group, were undertaken. Initial syntheses have centered on Y = TsO and Br. The preparations of these materials, as well as the reaction of the bromo compound with  $\text{Na}[\eta^5\text{-C}_5\text{H}_5\text{Fe}(\text{CO})_2]$ , will be presented.  
(Supported in part by JMU NSF-REU site grant.)

SYNTHESIS OF FOSSIL FUEL COMPONENTS: THE PENTADECYLPYRIDINES. Matthew Milkevitch and Wayne M. Stalick, Department of Chemistry, George Mason Univ., Fairfax, VA 22030. Alkylpyridines have been identified as major constituents of oil shale and lower rank bituminous and lignite coals. In order to develop a better understanding of the decomposition pathways of these materials, a study of the pyrolysis reactions of alkylpyridines is undergoing investigation. The model starting materials for these pyrolysis reactions are the three isomeric *n*-pentadecylpypyridines. Many smaller alkyl- and alkenylpyridines that are breakdown products of the pyrolysis reactions have been synthesized successfully in high yields by a modified Brown and Murphey synthesis using sodium amide in liquid ammonia. When this method was extended to the pentadecylpypyridines, disappointing yields were realized. Other methods of alkylpyridine synthesis also were tried with limited success. Recently an interesting observation was made that when catalytic amounts of calcium hydride are added to the reaction mixture, yields of pentadecylpypyridine products are increased markedly. A discussion of the methods employed during these syntheses and the effect of calcium hydride on product yields will be presented.

SOME ASPECTS OF THE ORGANIC CHEMISTRY OF PYRROLES AS MODIFIED BY COORDINATION TO PENTAAMMINEOSMIUM(II). W.H. Myers and L.K. Neely\*, Dept. of Chem., Univ. of Richmond, Richmond, VA 23173, and W.D. Harman\* and J.I. Koontz\*, Dept. of Chem., Univ. of Virginia, Charlottesville, VA 22901. The uncoordinated portion of pyrroles bound in an  $n^2$ -fashion to pentaammineosmium are found to react either as enamines or as azomethine ylids, giving access to a number of unusual and synthetically interesting products. The results indicate the role of the complexing osmium is to protect one double bond in the pyrrole while directing any chemistry to the face of the ring opposite the osmium, with stereospecific consequences. Tautomerization, cycloadduct formation, and Michael addition reactions of these complexed pyrroles will be discussed.

SOLUTION STRUCTURES OF MACROMOLECULES BY 3-DIMENSIONAL NMR TECHNIQUES David Rovnyak<sup>1</sup>, Raymond Dominey<sup>1</sup>, J. N. Scarsdale<sup>2</sup>,  
<sup>1</sup>Department of Chemistry, University of Richmond; <sup>2</sup>Dept. of Biochemistry & Molecular Biophysics, MCV-VCU, Richmond, VA.

Due to the tremendous advances in NMR spectroscopy over the past decade, the determination of the solution conformation of biomolecules has become relatively common using NMR data alone. Until now, these determinations required 2-D experiments on high-field (500 MHz or greater) instruments. Recently invented 3-D NMR experiments now promise sufficient spectral dispersion and simplification to permit the determination of the solution conformation of moderately large biomolecules on medium field instruments. For example, the HOHAHA-HOHAHA experiment spreads through-bond connectivities over three dimensions, while the HOHAHA-NOESY experiment spreads through-space connectivities over three dimensions. This provides significantly better resolution than the corresponding conventional 2-D experiments. We shall present data from 3-D NMR experiments applied to a 31-residue peptide on a 300 MHz spectrometer.

THE SYNTHESIS AND CATION BINDING STUDIES OF AN ISOCYANO FUNCTIONALIZED CROWN ETHER AND SELECTED TRANSITION METAL COMPLEXES. Marsi E. Shapiro, Elizabeth A. Smith, D. S. Amenta and J. A. Mosbo, Dept. of Chem., James Madison Univ., Harrisonburg, Va. 22807. Transition metal complexes containing crown ethers may allow for the study of cation binding that can significantly affect the properties of the complexes. This presentation reports the syntheses of the ligand 4'-isocyanobenzo-15-crown-5 and its platinum complex,  $L_2PtCl_2$ . The cation binding and extraction constants for the free ligand and the complex, have been studied utilizing  $^1H$ ,  $^{13}C$ , and  $^{195}Pt$  NMR, and UV/VIS spectroscopy. The results of the syntheses and the spectroscopic studies will be presented. (Supported in part by JMU NSF-REU site grant.)

FUEL INSTABILITY STUDIES: NITROGEN HETEROCYCLES AND SULFONIC ACIDS. Wayne M. Stalick and George W. Mushrush, Chem. Dept., George Mason Univ., Fairfax, VA 22030. Diesel fuels contain small amounts of polar nitrogen, oxygen and sulfur compounds, and many of these compounds have been implicated in the storage instability of fuels. Instability is defined in terms of the quantity of insolubles formed upon standing. Analysis of various middle-distillate fuel extracts has shown that the fraction which forms the most sediment contains the largest concentration of alkylindoles. It has been proposed that sediment formation results from the interaction of the heterocyclics with acids in the fuels. 3-Methylindole, when added to a fuel, was found to be a good promoter; whereas other nitrogen heterocycles such as 2,5-dimethyl-quinoline and 2-picoline were innocuous and carbazole was a mild promoter of instability. The sediments produced from the doping of shale diesel fuel were shown by MS to be very similar to the naturally formed insolubles. Elemental and spectroscopic analysis of the sediments show no incorporation of carboxylic acids, however, sulfonic acid incorporation is quite evident. The sediment formed when a model fuel system of Isooctane is doped with 3-methylindole and dodecylbenzene sulfonic acid will be related to the natural sediments from fuels and a mechanism of formation will be discussed.

RADIATION EFFECTS ON FILMS OF BORON-LOADED POLYMERS. Jean M. Stephens and Richard L. Kiefer, Dept. of Chemistry, College of William and Mary, Williamsburg, VA 23187. Neutrons are one of the products of the interaction of cosmic rays with materials. When reduced to very low energies, neutrons have large probabilities for interaction with matter. These particles can be absorbed with a high probability by boron-10, a stable isotope of boron. In this study, boron powder was added to two radiation resistant polymeric materials: a polysulfone, and a polyetherimide. Films of both materials with up to 20% by mass of boron were made. Infrared spectra taken before and after irradiation with 100 keV electrons showed that the modified materials behaved the same as the pure polymers when irradiated. Tests in a small neutron source showed that the boron-loaded films were effective in absorbing low-energy neutrons. (Jean Stephens is the recipient of a scholarship from the Virginia Space Grant Consortium.)

ACTIVE SITE LABELING OF THE GUANINE-7-METHYLTRANSFERASE. E. Streaker and T.O. Sitz, Dept. of Biochem., Virginia Tech, Blacksburg, VA 24061. Studies on the guanine-7-methyltransferase have defined three domains in the active site: the S-adenosylmethionine (SAM) region, the cap region (GpppG), and the RNA binding domain ( --NpNpNpNpNp-- ). We attempted to label the SAM binding domain by a photoaffinity label using 8-azido-SAM and another method using <sup>3</sup>H-SAM and long exposures to uv-light. Neither method was successful. The next approach was to attempt to label the cap-RNA binding domain (GpppGpNpNpNpNpN) by synthesizing RNA containing 8-azido-Ap using an in vitro transcription system and T7 RNA polymerase. The 8-azido-ATP inhibited the T7 RNA polymerase preventing the synthesis of RNA. As we were unable to synthesize the photoaffinity label, we next tried to synthesize an end labeled RNA and directly label by long exposures to uv-light. When the enzyme was incubated with <sup>32</sup>P-labeled RNA for 15 min at 37° and then exposed to a germicidal lamp for various times at 0°, optimal labeling occurred after 45 min. Various enzyme preparations were labeled by this method and two polypeptides were found to specifically bind the non-methylated mRNA analog. This labeling method should allow us to characterize the subunit structure and generate information about the nature of the RNA binding domain.

PHOTOACOUSTIC ANALYSIS OF THE SEALANT/SUBSTRATE INTERFACE. Mojgan Babai and J. P. Wightman, Dept. of Chemistry, Ctr. for Adhesive and Sealant Science, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. Unresolved questions remain concerning surface chemical aspects of the sealant/substrate interface. The application of photoacoustic infrared spectroscopy to this interface is described. Using polytetrafluoroethylene (PTFE) as a substrate, the decrease in the absorbance of the C-F stretch was determined as a function of increasing thickness of a polyurethane sealant overlayer. In a separate series of experiments, the peel strengths of polyurethane and silicone sealants to untreated and oxygen plasma treated polymer substrates were determined. The peel strength of a silicone sealant to PTFE increased some twenty-five times following a short time exposure to an oxygen plasma. The surface composition of the failed surfaces as determined by x-ray photoelectron spectroscopy (XPS) was consistent with the observed change in peel strength. [Research supported by The Adhesive and Sealant Council, Inc.]

THE CHEMISTRY OF 1,4-DIPIPERIDYL AND 1,4-DIPYRROLIDINO BENZENE. Roy L. Williams, Dept. of Chemistry and Biochemistry, Old Dominion University, Norfolk, VA 23529, and Sherry Williams\*, Newport News Water Works, Newport News, VA 23693. The above two compounds have been synthesized in this laboratory and have been shown to be effective colorimetric reagents for the detection of residual chlorine and ozone in drinking water. The mechanism of action for these compounds together with their analytical profile will be discussed. Several new analogs have been prepared in an effort to achieve greater sensitivity and selectivity in these measurements. A novel polymer synthesis related to this class of compounds will be described.

CHROMATOGRAPHIC ANALYSIS FOR POLYPHENOLICS IN VIRGINIA WINES AND GRAPE COMPONENTS. Roy L. Williams, Dept. of Chemistry and Biochemistry, Old Dominion University, Norfolk, VA 23529 and Jacques Recht\*, Ingleside Plantation Vineyards, Oak Grove, VA 22443. This paper will describe our research into the isolation and identification of various polyphenolic components found in Virginia wines and grape extracts. These flavonoid compounds have been shown to be of interest as potential positive health factors associated with the consumption of wine. Our analytical methods of separation and identification will be described together with data related to specific red wine varietals from various Virginia wineries. The development of these polyphenolics during the fermentation process will be described from cabernet sauvignon wines from Ingleside Plantation Vineyards.

SYNTHESIS AND CHARACTERIZATION OF PROTEINOIDS PREPARED BY CONDENSATION WITH DIPHEYL PHOSPHORYL AZIDE. Jian-Zhong Yang and Raphael Ottenbrite, Dept. of Chem., Va Commonwealth Univ., Richmond, Va.23284. Novel synthesis of poly(amino acids) through direct polymerization of  $\alpha$ -amino acids using diphenylphosphoryl azide (DPPA) as a condensing agent was studied. Homo- and co-poly(amino acids) having molecular weight up to 30,000 and polydispersity about 1.7 were easily prepared by stirring a suitable solution of an amino acid in the presence of DPPA and triethylamine (TEA). The yield as well as the molecular weight of the polymers was found to be dependent on the concentration of the monomer, the polymerization temperature, and the ratios of [DPPA]/[Asp.Bz] and [TEA]/[Asp.Bz]. In general, increasing the monomer concentration and lowering the polymerization temperature tend to increase the molecular weight. With the  $[M] > 0.2$  g/mL, a bimodal molecular weight distribution was observed. The highest yield and higher molecular weight of the polymer were obtained in the range of [DPPA]/[Asp.Bz] of = 1.3 - 2.0 and [TEA]/[Asp.Bz] = 2.0 - 3.0. The polymerization behavior is influenced by the solvents used. The characterization of the resulting copolymers was carried out by NMR, IR, and GPC spectroscopies.

SYNTHESIS OF POLY(MALEIC ANHYDRIDE-CO-2-PROPYENYL BENZENE-3,4-DIACETATE). S.Imran Zaidi and R.M.Ottenbrite, Chemistry Dept., Virginia Commonwealth Univ., Richmond VA 23284.

The purpose of this study is to synthesize molecular weight controlled poly(maleic anhydride-co-2-propenyl benzene-3,4-diacetate). This polymer is known to elicit biological activity against tumor systems. The effect of initiator concentration, monomer concentration and temperature on the molecular weight and yield of polymer were evaluated. It was found that all these variables had an influence on both the molecular weight as well as yield. The polymer having molecular weight of 5,000 to 23,000 were synthesized with relatively narrow polydispersity at 65 to 85° C for 24 hours using AIBN as initiator.

## Computer Science

THE DEVELOPMENT OF AN X-WINDOW INTERFACE FOR AN INTERACTIVE APPLICATION PROGRAM WITHIN AN ALLBASE/SQL ENVIRONMENT. Kathy Altman and Prof. Rita D'Arcangelis, Dept. of Computer Science, Mary Washington Col., Fredericksburg, VA 22401. In an integrated database environment sophisticated users can be trained in the use of an on-line query language, and can access data by entering queries at the terminal. Naive users, however, access data through applications programs that have been written for them. These programs may be either batch or on-line, may be written in a variety of host programming languages, such as C, Pascal, COBOL, or FORTRAN, and manipulate stored data through embedded query language commands. For interactive applications, an attractive option is to further support the naive user by means of an easy-to-use I/O interface. We report on an experiment to include an X-window, menu-driven, data entry and edit interface in a sample university database system for naive users in the registrar's office. The system was implemented on a UNIX-based Hewlett Packard HP 850 super minicomputer using an ALLBASE/SQL relational DBMS with Pascal as host. When the user selects an activity via mouse, the X-window graphics interface software (written in C), invokes Pascal SQL programs to make the database available for access.

A MULTI-PROCESSOR NETWORK FOR EVENT BUILDING. Robert F. Hodson, Department of Physics and Computer Science, Christopher Newport College, Newport News, Va. 23606. The focus of this research is to study the feasibility of a multiprocessor network for the event building task. The approach presented is a departure from methods previously used to perform the event building task which is part of a high speed data acquisition system for the CEBAF National Laboratory. The paper initially reviews the data acquisition system, specifically concentrating on the event building task for real-time assembly of multiple data streams. The requirements of the event builder are presented, providing information on sustained data rates, number of data streams and other system details. A survey of potential multiprocessor networks is given. Simple rings, dual rings, and hypercube networks are considered. The performance of the various networks for the event building task are studied and their performance is evaluated relative to the system's requirements. The network performance is primarily based on system simulations using the Verilog-XL hardware simulator. Other network performance predictors are derived or based on C programs. Multiple network topologies and routing algorithms are studied. Following the network analysis, consideration is given to processors for network implementation. Trade-offs between network topologies and the I/O bandwidth of various communication processors are considered. The focus of this work is on studying the capabilities of the T9000 transputer (although some consideration is given to the TMS320C40 DSP). Finally, a proposed system is presented along with a suggested implementation. (Supported by CEBAF National Laboratory.)

A TAXI SERVICE—AN EXERCISE IN SIMULATION WITH ADA. Torrin Sanders and James Irvin, Department of Computer Science, Hampton University, Hampton, VA 23668 The ADA simulation of a taxi service attempts to mimic the real-time actions of a taxi dispatcher. The unique tasking capabilities of the ADA programming language allows the concept of concurrency to be applied to the simulation. The taxis used in the program are created according to a user-defined taxi pool. Several tasks exist to perform calls between the dispatcher and the customers requesting a cab. Originally, the length of time the taxis were allowed to perform their duties was determined by a special time delay function. Our latest development has lead to the generation of a city map which will send a path determined by a search algorithm to the dispatcher so that the taxi will know how to reach its fare.

USING PSEUDO CLASSIFIERS TO REDUCE SEARCHES. Robert A. Willis, Jr., Department of Computer Science, Hampton University, Hampton, VA 23668 Classifiers are highly parallel entities which respond to external stimulus. Behavior of a classifier system is at first predicted by a pre-programmed set of rules. Behavior changes (classifiers learn) as each classifier responds to external stimuli and weigh the success of its response. If the response is unsuccessful the rule is mutated based on some criteria. Pseudo classifiers are highly parallel entities whose function are (among other things) to reduce searches in a network. Once a particular search has been made, a pseudo classifier "remembers" the result and if the same request is made again, the answer is immediately forthcoming.

## Education

STRUCTURING ORGANIC LABORATORY AS A RESEARCH EXPERIENCE: THE NORMAL APPROACH WITH A TWIST. Lisa T. Alty, Dept. of Chem., Washington and Lee Univ., Lexington, VA 24450. One way to demonstrate a research experience in the sophomore organic laboratory is to mimic the organizational process of a research laboratory scientist. This can be done by structuring the laboratory with multiple experiments being performed simultaneously. Students must prepare extensively in order to decide the time needed to carry out experiments and how to overlap nonproductive times in one experiment with productive gains in other experiments. The skills students develop in both technique and time management serve them well in later scientific research laboratory experiences and in their professional lives.

A COMPARISON OF MONTESSORI AND CONVENTIONAL PRESCHOOL LEARNING: A PILOT STUDY OF THREE-YEAR-OLDS' PERFORMANCE ON AGE-APPROPRIATE COGNITIVE TASKS. Linda Beeler, Teresa Richardson, Patricia Ward, Va. Beach Campus, Tidewater Cmnty. Col., Va. Beach, VA 23456. Many preschools base their curriculums on either the Montessori or the Conventional (Social-Interactive) approach to teaching. Research has shown that neither approach is associated with differences in later learning. Do very young children with minimal school experience exhibit different cognitive abilities because of the teaching approach used? Subjects were 20 Montessori and 20 Conventional three-year-olds from similar middle income backgrounds and gender distributions. The two groups were compared on 7 cognitive tasks designed for three-year-olds from the Developmental Indicators for the Assessment of Learning-Revised (DIAL-R): identifying body parts, naming colors, rote counting, meaningful counting, positioning objects, identifying concepts, and matching shapes. Means for percent total and for each of the 7 subtests were virtually identical (maximum difference was one point); medians for percent total correct as well as 6 subtest medians were identical. The largest difference of medians observed was .5 for rote counting. Future research would focus on tests of cognitive factors at higher levels. Behavioral factors including self-control, task orientation, task completion, and social interaction should also be evaluated.

A STUDY OF PARTICIPATION AND ACHIEVEMENT OF BLACK, HISPANIC AND FEMALE STUDENTS IN SCIENCE, MATHEMATICS, AND ADVANCED TECHNOLOGIES. Tim Cotman, State Dept. of Education, P.O. Box 6-Q, Richmond, VA 23216-2060. Current literature describes a lack of participation and achievement of minority students in science, mathematics and advanced technologies. Research suggests that some minority students, especially black and Hispanic, have significantly lower achievement in mathematics, science and technology courses than do white students. This study assessed the participation and achievement of black, Hispanic and female students in science, mathematics and technology courses as compared to white students and male students, as appropriate, in Virginia public schools. Educational intervention strategies which have been successful in reducing the disparity in minority and female participation and achievement in these subject areas in secondary schools are included in this report.

COOPERATIVE PRECOLLEGE EDUCATIONAL PROGRAMS AT THE CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY (CEBAF), by Beverly Hartline and Kathryn Strozak, Education Dept., Continuous Electron Beam Accelerator Facility, 12000 Jefferson Avenue, Newport News, Va. 23606. The Continuous Electron Beam Accelerator Facility (CEBAF), under construction in Newport News, Virginia, is a particle accelerator laboratory for nuclear physics research funded by the U.S. Department of Energy. CEBAF's research and supporting technologies offer a rich environment for capturing the interest of and augmenting the experiences of precollege teachers and students. This presentation will discuss some of the precollege educational programs underway at CEBAF in collaboration with schools, colleges, and business partners. The purpose of CEBAF's educational programs are to motivate students, support teachers, and involve parents. The BEAMS program -- Becoming Enthusiastic About Math and Science -- is highlighted. BEAMS brings entire classes of fifth and sixth grade students with their teachers into CEBAF for a full school week of special science and math activities and contact with scientist, engineer, and technician role model volunteers. A pilot program involving seven inner-city classes was conducted in spring 1991. The 1991/1992 program is well underway with fifty classes scheduled to visit CEBAF. Teachers are supported by CEBAF's educational program's by being brought into the science establishment as partners and participants and being provided access to expertise and equipment.

ASSESSMENT IN A CONSTRUCTIVIST CLASSROOM. George E. Glasson and Rosary V. Lalik\*, Div. of Curriculum and Instruction, Virginia Polytechnic Institute and State University, Blacksburg, VA. 24061-0313

The purpose of this analysis is to contribute to the emerging dialogue about alternative assessment practices in constructivist science classrooms. In particular, we discuss how social constructivists emphasize the development of students' identities as science learners through participation in communities of practice. Essential to participation is students' reciprocal use of dialogue and action and the negotiation of meaning of scientific phenomena. From this perspective, assessment systems cannot be based solely on acquisition of scientific knowledge, but instead should focus on examining students' understandings while attending to larger concerns about the purposes of education within a democratic and pluralistic society.

REFLECTIONS UPON THE 2ND INTERNATIONAL CONFERENCE ON HISTORY AND PHILOSOPHY OF SCIENCE IN SCIENCE TEACHING. Kenneth S. Lawwill and Edgar D. Morris, Jr. Curr. & Inst. Div., Va. Polytechnic Inst. & State Univ., Blacksburg, VA. 24061-0313. Held in Kingston, Ontario, May 11 - 15, 1992, this conference provided the opportunity to interact with others from twenty-plus countries. The participants held numerous perspectives concerning science education. Social constructivism was a dominant theme. Science-Technology-Society concerns also were a focus. Women's concerns regarding science and science ed. were well represented and voiced. Efforts were attempted to bridge the gap between the scholars and the practitioners. Unfortunately, there were still some who wished to promote their own viewpoint rather than engage in dialogue. For the authors, one of the most powerful messages was the American ethnocentric viewpoint of "self" is not representative of many cultures who focus more on community concerns. This has strong implications when designing curricula that is pertinent for the students.

COOPERATIVE LEARNING AND QUANTITATIVE LABORATORY EXPERIENCE. Kenneth S. Lawwill, Curr. & Inst. Div., Va. Polytechnic Inst. & State Univ., Blacksburg, VA. 24061-0313. Quantitative lab experiences are dreaded by some students due to anxiety concerning accuracy and the "price" of mistakes. Further, it is not representative of actually practice of most science to generalize from but a few data points. Recognizing the validity of data and whether this data can be "productive" is an important ability in science. Pooling the class's data and allowing the students to discuss merits and statistically remove outliers provides for learning experiences that individual analysis can not allow. The strengths of cooperative learning have been repeated reported in the educational literature. These include increased student comprehension, synergy of ideas, and positive influences upon self-esteem and social skills. Allowing students to work together will increase discourse pertaining to the subject, and thus involved more reflection by the students and more activation of prior knowledge.

SHARED UNDERSTANDINGS IN THE SCIENCE CLASSROOM Edgar D. Morris, Jr. Div. of Curriculum & Instruction, Coll. of Educ., VA Tech, Blacksburg, VA 24061  
Social constructivists like Vygotsky have emphasized the importance of dialogue and action in making sense of the world. This world includes education and even more specifically the science classroom. Those that participate in the dialogue and actions while trying to understand and be understood, develop shared languages, tools and understandings. The encouragement of developing shared understandings could be seen as a goal of educators for developing citizens sensitive to others' opinions for the sake of global awareness. Observing the dialogue and actions of students sharing their ideas seems to be a way in which to determine if shared understandings are indeed important in schools.

The researcher/participant worked with an eighth grade physical science class that was encouraged by their teacher to dialogue with one another for the purpose of developing group projects. During the group discussions the teacher acted as participant and facilitator not as lecturer. The dialogue and actions of the students and their teacher were examined as if through the eyes of different social constructivists. This is because the researcher recognizes the fact that each of the social constructivist's points of view impact his own. As the researcher describes the dialogue and actions of his target group through these different points of view, possible explanations of the group's shared understandings emerged. All explanations had one common theme. The skills needed in developing shared understandings can be obtained through practice.

SCIENCE LITERACY AND STS - CONNECTIONS OR CONFLICTS? Thomas G. Teates and Kenneth S. Lawwill, Div. of Curriculum and Instruction, Va. Polytechnic Institute and State Univ., Blacksburg, VA 24061. It appears that the current STS emphasis in science education has the potential to positively impact the severe lack of science literacy exhibited by the U. S. populace. The National Assessment of Educational Progress continues to document the poor performance of school age youth through age 17. If the effort to use a STS theme to focus student interest on "real-world" problems and thereby gain greater interest in science does not also give major effort to consideration of global problems such as unchecked population growth and the extreme inequities in the distribution of the earth's resources, then the STS movement will merely be another failed effort to bring meaningful reform to science curricula.

IMPLICATIONS OF REFORMS IN SCIENCE EDUCATION. Pamela C. Turpin, EdCI, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. We have seen reform after reform in science education. Sometimes it seems as if we are going through reform cycles. We try something new only to try it as "new" again in twenty years. Today, the Science/Technology /Society reform movements in science curricula call for a more interdisciplinary approach to science education. Combined with a constructivist's theory of learning, these reforms re-define the tradition role of the science teacher. The transformation of curricula means more than just the introduction of a new text. Teachers must be prepared to meet the challenge of new methods of teaching. New curricula do not magically transform the teacher's skills and abilities. We must answer the question, "What is the new role that science teachers need to fulfill in these reform movements and how is that role to be accomplished?" Throughout all of the different reforms we have tried in science education, perhaps we have overlooked the most important component of those reforms -- the teacher. The reforming of "how" we teach may be more important than the "what" we teach. The only way to reform the "how" is to educate or re-educate the teacher, not devise curricula that say "do it this way". Teachers, as well as students, need a multifaceted education that will enable them to become creative, productive, autonomous individuals.

1992 SCIENCE FAIR SURVEY. Lynn P. Wilson and Lillian J. Clark\*, Virginia Power, Richmond, Va., 23261. Results of a corporate study of science fair activity in Virginia schools in which public school principals, PTA presidents and members of the Virginia Association of Science Teachers were surveyed. Seventy-two percent of the respondents had held a science fair within the past three years. Of these, 64% sent exemplary projects onto higher levels of competition: 73% to regional science fairs; 50% to school division science fairs and 17% to the Virginia Junior Academy of Science.

## Environmental Science

COMPARATIVE RESPONSE OF THE ASIATIC CLAM, *CORBICULA FLUMINEA*, AND THE ZEBRA MUSSEL, *DREISSENA POLYMORPHA*, TO OSMOREGULATORY STRESS. Joseph R. Bidwell, Don S. Cherry, and Jerry L. Farris, Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0406. Laboratory and field bioassays were conducted to determine the sensitivity of the Asiatic clam, *Corbicula fluminea*, and the zebra mussel, *Dreissena polymorpha*, to a surfactant based molluscicide. In addition to assessing mortality after exposure to the chemical, selected biochemical variables were examined to determine a possible mode of action. At both low (15 °C) and high (25 °C) temperatures, *Dreissena* was found to be more sensitive than *Corbicula*. Sharp increases in whole body tissue water content were observed in both organisms following exposure, indicating the induction of osmoregulatory dysfunction. In those cases in which *Corbicula* survived exposure, tissue water content returned to pre-stress levels. Similar regulation was not observed in *Dreissena*. When the two bivalves were exposed to a hyperosmotic stress (5 0/00 salinity water), *Corbicula* also maintained body volume more effectively than *Dreissena*. Based on these data, it is believed that the differential response to the surfactant based molluscicide may be in part due to a better ability of *Corbicula* to deal with the osmotic stress associated with exposure. The ability to handle this osmotic stress may itself be due to the retention of physiological capabilities stemming from a brackish ancestry.

PHYTOPLANKTON STUDIES IN A TIDAL FRESHWATER ECOSYSTEM. Jianfeng Chen, Dept. of Biol., George Mason Univ., Fairfax, VA 22030. Phytoplankton were enumerated by species on samples collected on a biweekly to monthly basis in 1991 from 5 sites on the tidal freshwater Potomac River. Cell densities of major groups and species were analyzed to determine spatial and seasonal variation. Phytoplankton densities were higher in the two embayment areas than in the river mainstem. A dramatic increase in phytoplankton was observed from May through August with a rapid decline in September and October, caused mainly by changes in various cyanobacterial species. Dominant cyanobacterial species included Merismopedia tenuissima, Chroococcus dispersus var. minor, Oscillatoria planktonica, Merismopedia punctata, and Aphanocapsa sp.. Diatoms were dominant in spring and the most numerous species were Melosira sp. and small discoid centrics (3-5  $\mu\text{m}$ ). Cryptophytes became important only early and late in the year. The green algae were uniform in their contribution to phytoplankton density over the whole year.

POPULATION DYNAMICS OF BOSMINA LONGIROSTRIS IN A TIDAL FRESH-WATER ECOSYSTEM. Theresa E. Connor, Dept. of Biol., George Mason Univ., Fairfax, Va. 22030. The population dynamics of *Bosmina longirostris* in the Gunston Cove area of the tidal freshwater Potomac River were investigated through weekly sampling at five stations. Parameters quantified were population density, average size per individual, and egg production. Low densities in March and April were followed by a rapid increase in early May. A decline in late May and early June was followed by a second increase in late June. Each period of increase coincided with increases in eggs/female and declines coincided with decreases in eggs/female indicating that population dynamics were related to changes in fecundity.

THE DEVELOPMENT OF A FLOW THROUGH ALGAL TOXICITY TEST UTILIZING THE GREEN ALGA *CHLORELLA VULGARIS*. Michael G. Dobhs, Don S. Cherry, and John Cairns, Jr., Dept. of Biology and Ctr. for Environmental Studies, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. This research is the first phase of a larger project to develop a "trophic toxicity test". To provide a physiologically stable source of algae for higher trophic levels a flow through algal toxicity test utilizing a chemostat design has been developed to examine copper toxicity to *Chlorella vulgaris*. Some benefits of the chemostatic design as compared to standard algal bottle tests are: continuous renewal of toxicant; stable physiological state of the algae; and the ability to study the adaption of an algal population to a toxicant. Copper toxicity was evident within one day of adding the copper to the algae. Four day LOEC's of 160 and 100 ug Cu/L (hardness = 160 & 100 mg/L as CaCO<sub>3</sub>) were derived using the flow though algal toxicity test. Corresponding NOEC's were 80 and 50 ug Cu/L. Addition of 50 ug Cu/L to the algal chemostats cause a initial decline in the algal population, but the algal population recovered to control levels by the sixth day. Algal bottle tests had lower LOECs (10 & 12 ug Cu/L), but failed to detect the ability of the algal population to acclimate to the toxicant.

RELATIONSHIP BETWEEN NUTRIENTS AND PHYTOPLANKTON IN A TIDAL FRESHWATER ECOSYSTEM. R. Christian Jones, Dept. of Biol., George Mason Univ., Fairfax, VA 22030. Concentrations of nitrogen and phosphorus forms and phytoplankton densities by species were determined at 12 stations in the Gunston Cove area of the tidal freshwater Potomac River. A positive relationship was observed between particulate nutrients and phytoplankton, but dissolved nutrients appeared negatively related to phytoplankton densities. Percent cyanobacteria, the dominant phytoplankton group by cell number, was positively related to total phosphorus, but not clearly related to forms of nitrogen. A negative relationship was suggested between percent cyanobacteria and total nitrogen to total phosphorus ratio in Gunston Cove proper, but not in the nearby river mainstem or in the Dogue Creek embayment.

SUBSURFACE HYDROCARBON CONTAMINATION INCIDENT IN FAIRFAX COUNTY. Douglas Mose, George Mushrush, and Charles Chrosniak, Center for Basic and Applied Science, George Mason University, Fairfax, VA 22030.

In the center of Fairfax County (located in northern Virginia), a fuel storage terminal released >100,000 gallons of liquid hydrocarbon fuels into the underlying soil. The first evidence occurred in September of 1990, when fuel oil appeared on a local stream. Monitor wells revealed the elongated geology-dominated orientation of the plume in 1992. A local home >2000 feet from the fuel storage terminal was evacuated in early 1992, when explosive vapors invaded the basement. Studies reveal that the subsurface plume consists of gasoline and middle distillate fuels (jet A and diesel). The total plume area reached about 500 feet across and 2500 feet long by spring 1992, and evidence indicates the free product is continuing to advance. Rapid subsurface movement (est. = >100 feet/month) along zones of enhanced permeability have prevented containment, and may prevent remediation.

A PRELIMINARY FLORAL SURVEY OF THE GINGOTEAGUE CREEK WETLANDS, A FRESHWATER TRIBUTARY OF THE RAPPAHANNOCK RIVER. Brian L. Patrick, W. Wieland, C.N. Curtis\*, and C.C. Perusi\*, Dept. of Biol. Mary Washington College, Fredericksburg, Virginia 22401, and Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia 23062. A total of 72 species representing 55 genera and 35 families were identified. These species were identified by running transects from the mean waters edge to the lowland shrub population. Every 5 to 10 meters of the transect a one (1) square meter quadrat was evaluated for species and rough density by percentage. The wetlands showed much diversity. Different communities were found depending on the makeup of the wetlands. Dominant species include Peltandra virginica (Arrow Arum), Zizaniopsis miliacea (Southern Wild Rice), Zizania aquatica (Northern Wild Rice), numerous Bidens spp., and numerous Polygonum spp.

AN ENVIRONMENTAL PERSPECTIVE ON RECOMBINANT RABIES VIRUS FIELD TRIALS. Jane Rissler\*, National Wildlife Federation, 1400 16th St., N.W., Washington, DC 20036. The vaccination of raccoons with recombinant rabies vaccine is the first U.S. release of a genetically engineered virus in wildlife. To assure the public of the safety of these releases, NWF has urged the federal government to establish standards for full review of risks and benefits of the proposed releases and for meaningful public participation in decisionmaking. Despite laboratory and field testing, the environmental release of recombinant rabies/vaccinia virus raises long-term risk questions, such as the potential for new viruses through recombination, new vaccinia reservoirs, and effects on non-target organisms and immunocompromised humans. The benefits of the vaccine have yet to be critically analyzed. Population models indicate that vaccination of 99% of raccoons may be needed to eradicate rabies. This degree of vaccination is unlikely to be attained, except perhaps in small, localized areas.

## Geography

A GEOGRAPHIC ANALYSIS OF RECYCLING IN VIRGINIA. Warren Crowder, Mary B. Kimsey, & Charlie Nalley, Dept. of Geology/Geography, James Madison Univ., Harrisonburg, Va. 22807. Throughout the United States, old landfills have been closing, with few new landfills to replace them. As a result, the disposal of solid waste is becoming increasingly expensive. In response, the Commonwealth of Virginia has issued a mandate requiring every city, county and town to develop a solid waste management program. Recycling of household waste is to be a major component of this program. It was to be the goal of each city, town and county to be recycling 10% of all household waste by December 31, 1991. By December 31, 1993, this figure is to be increased to 15%. An analysis of curbside collection programs in the state of Virginia reveals that some highly urban counties and some of the largest cities still have no curbside recycling. At the same time, some rather rural counties and small towns do have curbside recycling. The reasons for this are varied.

THE PRE VOYAGE GEOGRAPHY OF CHRISTOPHER COLUMBUS. Joseph D. Enedy & Mary B. Kimsey, Dept. of Geol. & Geog., James Madison Univ., Harrisonburg, Va. 22807. This presentation explores the issue of what Columbus knew of the world, especially the little known world of the western sea prior to his first voyage. Scholars have searched the few original sources and have speculated a great deal to portray a man who selectively chose information that would further his appeals for support while at the same time acquiring first hand experience in navigation. Evidence from writings of the day, stories from the islands off the coast of Portugal, his own seafaring experience and the actual routes taken are used to show that Columbus had not solved the problem of sailing west to reach the east, but did possess the navigational experience to cross the Atlantic and return to sail again.

WILDERNESS INFORMATION SPECIALISTS: A REPORT ON EFFECTIVENESS. Jack Gentile, Dept. of Geog., James Madison Univ., Harrisonburg, Va. 22807. This paper discusses the effectiveness of a wilderness information program implemented in the St. Mary's and Ramsey's Draft Wildernesses during the summer, 1991. Five Wilderness Information Specialists (WIS) were employed under a grant awarded from the George Washington National Forest. Approximately 500 visitors were contacted by the WIS. Each contact involved a discussion of no-trace camping and wilderness ethics. Fifty percent of the WIS effort was devoted to this activity. Although most people indicated being familiar with no-trace camping, all of the WIS indicated observing "inappropriate" camping techniques subsequent to the contact. Approximately 25% of the WIS effort was devoted to campsite rehabilitation and trail maintenance. Another 25% of time was spent assessing user impacts, characteristics and activities. The derived data will provide information necessary to develop effective management prescriptions.

WILDERNESS RECREATION IN VIRGINIA: A REPORT ON VISITOR CHARACTERISTICS. Erin Goewey, Tim Connell and Jack Gentile, Dept. of Geog., James Madison Univ., Harrisonburg, Va. 22807. Surveys were obtained from 211 visitors of St. Mary's (SM) and Ramsey's Draft (RD) Wildernesses. The survey found RD users to be older, and visit less often than SM users. Hiking and camping were the preferred activities at both wildernesses. Ninety-eight percent indicated that the wilderness fulfilled expectations. Of those unsatisfied, 81% still found the experience enjoyable. Of the RD users 69% felt no crowding, whereas at SM, only 39% felt no crowding. Eighty-one percent indicated that they were familiar with no-trace camping. However, only 69% practice no-trace methods. RD users would be more willing to pay a user fee than SM users. Finally, the preferred means to reduce impacts was to establish more wilderness. Initiating user fees, permits, or other types of control methods was not supported.

A COMPARISON OF USER IMPACTS IN TWO VIRGINIA WILDERNESS AREAS. Eric West, Darren Coffey, and Jack Gentile, Dept. of Geog., James Madison Univ., Harrisonburg, Va. 22807. Assessment of campsites in the St. Mary's and Ramsey's Draft Wildernesses was completed using a newly developed quantitative field procedure. The procedure measures six variables to arrive at a Condition Class value for each site. A total of fifty-eight campsites were inventoried in St. Mary's. Of these, 43 were first inventoried in 1989. Eleven sites were determined to be highly impacted. A comparison of the 43 sites from the 1989 data found 15 sites unchanged, 24 in better condition, and 4 sites worse than in 1989. Even with these improvements, the overall impacts are increasing. A total of 40 campsites were inventoried in Ramsey's Draft Wilderness. Only five sites are heavily impacted. Tree damage and bare ground are the most frequently occurring signs of human impact. Most of the sites appear to be used infrequently. Further, unlike the conditions at St. Mary's Wilderness, the heavily impacted sites show no signs of geographic clustering.

MAKING A CASE FOR USING COMMON LOGARITHMS AS A CLASS INTERVAL METHOD FOR DATA CLASSIFICATION IN CHOROPLETH MAPPING. Stephen E. Wright and Eric S. West, Dept. of Geol. and Geog., James Madison Univ., Harrisonburg, Va. 22807. The purpose of this paper is to introduce the use of logarithms as a choroplethic class interval technique. Discussed is the simplicity and appropriateness of using logarithms for class interval section. To effectively illustrate the logarithmic class interval method, several practical examples are provided.

THE SPATIAL DISTRIBUTION AND GEOGRAPHIC ANALYSIS OF ENDODONTIST OFFICE LOCATIONS AT THE NATIONAL SCALE. Stephen E. Wright, Dept. of Geol. & Geog., James Madison Univ., Harrisonburg, Va. 22807. The purpose of this study was to quantify and describe the spatial distribution of Endodontist office locations at the national scale.

Research questions were: 1) Does the spatial distribution of Endodontist office locations exhibit a significant spatial autocorrelation?; 2) What is the degree of concentration of endodontist within the U.S. when measured at the National or Macro scale?; and 3) In terms of spatial structure how are the dependent and independent variables of Endodontist organized spatially? Spatial autocorrelation, descriptive statistics and correlation analysis were the analytical tools selected for analyzing the data. It was found that the spatial distribution of Endodontist office locations did exhibit significant spatial autocorrelation. Also, Endodontist tend to concentrate in only ten states in the U.S., with northeastern regions of the nation having the greatest concentrations. Only the spatial distribution of U.S. population ( $r=.9266$ , sig.0001) and General Practice Dentist ( $r=.9491$ , sig. 0001) correlated with the spatial distribution of Endodontist office locations.

## Geology

ALLUVIAL CONGLOMERATES ALONG THE NORTHWEST BORDER OF THE RICHMOND BASIN. Russell A. Anthony, Department of Geology, College of William and Mary, Williamsburg, VA 23187-8795  
A band of alluvial conglomerate, approximately two hundred meters wide and six kilometers long, is located adjacent to the faulted western margin of the Richmond Basin. These alluvial deposits have been interpreted as the basal strata of the Richmond Basin and more recently as an accumulation of talus at the base of a scarp. This study recognized four lithofacies within a cross-sectional outcrop of the "Boulder Breccia". They include clast-supported conglomerate, matrix-supported conglomerate, horizontally-bedded sandstone and horizontally-stratified sandstone. Association of these four lithofacies suggests deposition by braided streams within an alluvial fan system. Large angular clasts suggestive of talus deposits were not encountered but likely occur locally within the "Boulder Breccia".

THE DUTCH GAP FAULT SYSTEM IN THE TRI-CITIES AREA- PRELIMINARY RESULTS OF A MICROGRAVITY SURVEY. Earl H. Budke, Jr., \*Dept. of Geological Science, Va. State University, Petersburg, VA 23803. The Dutch Gap fault system, as currently described, extends from Stony Creek in the south, to the James River in the north. It is a subsurface zone of reverse faults striking north, and dipping east. Preliminary interpretation of a gravimeter survey of 6000 readings made approximately fifty feet apart along many roads in the area indicates much greater complexity. Topographic effects mask the small anomalies along many traverses. In one area the gravity fault lies considerably east of the map fault. At least three other anomalies-faults lie within two miles, to the west, of the Dutch Gap and seem to run parallel to it. The Dutch Gap may form the eastern edge of a graben-like structure, through which the Appomattox and James Rivers flow. Two northeast-southwest trending faults intersect the Dutch Gap near Puddledock Road in Petersburg and indications of other faults have been found. (unfunded research)

PRESERVATION OF PLEISTOCENE BEACH RIDGES ON THE FOWLING POINT MARSH, SOUTHERN DELMARVA PENINSULA, VIRGINIA. Vistasp P. Dalal, Chesapeake Bay Special Proj. Prog., MD. Dept. of Envir., Baltimore, MD. 21224. Fowling Point Marsh, a mainland fringe salt marsh, on the Southern Delmarva Peninsula, uniquely exhibits the presence of relict beach ridges representing the Wachapreague Fm. and forming a part of the 'Bell Neck Sand-Ridge Complex'. After their formation, during Late Sangamonian-Early Wisconsinian period, the beach ridges subsequently went through several spatial and temporal stages (I-V) controlled by the predominant preservational and degradational processes (mainly marine and eolian) acting on them. Fowling Point Marsh represents one of the final stages in the preservation of the beach ridges in the geologic record accomplished by the burial of the beach ridges with marsh muds. Since the beach ridges are not common in the geologic record their temporary (?) presence on the Fowling Point Marsh is highly significant in the paleoenvironmental reconstruction of the Southern Delmarva Peninsula during Sangamonian-Wisconsinian period.

NOMENCLATURE AND STRATIGRAPHY OF THE MARTINSBURG AND REEDSVILLE FORMATIONS IN VIRGINIA AND ADJACENT STATES. Richard J. Diecchio, Dept. Geography and Earth Systems Science, George Mason Univ., Fairfax, VA 22030-4444. At Martinsburg, West Virginia, and elsewhere in the Shenandoah Valley of Virginia and Great Valley of Pennsylvania, the Martinsburg Formation consists of dark shales and turbidites interpreted as having been deposited in a deep flysch basin. At Reedsville, Pennsylvania, the Reedsville Formation contains interbedded shales, limestones and sandstones, interpreted elsewhere as having been deposited on a storm-dominated shelf. These two formations are approximately the same age, Middle to Upper Ordovician. Strata that are lithologically and temporally equivalent to the Reedsville Formation occur throughout the Central Appalachians west of the Martinsburg outcrop belt. The term Martinsburg Formation is commonly used throughout Virginia and West Virginia, even though the Reedsville lithology is much more widespread than the Martinsburg. Usage of the term Reedsville Formation to describe the appropriate strata is recommended.

COMPLEX RESPONSE OF A CHANNELIZED STREAM, ALEXANDER COUNTY, IL, L. Scott Eaton, Dept. of Geology and Geography, James Madison University, Harrisonburg, VA 22807. Wolf Creek, a gravel-bed load stream in northeastern Alexander County, Illinois, has undergone significant geomorphological changes as a result of stream channelization, logging, and intensive farming practices. Straightening of the Wolf Creek channel between 1927 and 1938 reduced the channel length by 30-35%. The reduction in stream length increased the stream gradient, triggering channel incision in the lower reach of the channelized section. As the incision progressed upstream, alluvium eroded from the channel was transported downstream and deposited in the lower reaches, thereby increasing the channel elevation. This process of cutting and filling is thought to have gradually lowered the channel gradient, and will probably continue to do so until the equilibrium of the stream is restored. Channel filling was sufficient to cause Wolf Creek to avulse onto the floodplain in 1981. As a result of the avulsion, discharge into a Wolf Creek Tributary was increased and may be causing the tributary channel to widen in its lower reaches.

AN ASSESSMENT OF THE FUNCTIONING OF THE STATE GEOLOGICAL SURVEYS IN THE LAST DECADE OF THE 20TH CENTURY. H. Grant Goodell. Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22903. All 50 states now have functioning State Geological Surveys. They range in size from those with a single State Geologist (New Hampshire) to large multi-division surveys which employ more than 100 professionals and an even larger support staff (Texas). More than one half of the surveys are administered by a state agency responsible for natural resources or conservation. Sixteen are associated with state universities. The remainder are independent agencies reporting to the Governor. The largest and best funded are found in states with large mineral and fuel resources and most of the thriving Surveys have widespread environmental responsibilities. In Colorado for example, the Survey is even responsible for snow avalanche forecasting! In Wisconsin the Survey is responsible for climatology. In big Surveys with wide responsibilities such as Illinois, largescale, interdisciplinary multiagency environmental and geological/hydrological research projects have become a major aspect of their activities. All of the Surveys which are successful have active public affairs and educational programs. If Virginia's Division of Mineral Resources is to survive and prosper it must be given a larger statutory mandate in the areas of environment assessment and natural hazards risk management in addition to its traditional role of geologic mapping and mineral resource evaluation.

NEW EVIDENCE FOR THE INTRUSIVE ORIGIN OF THE OLD RAG GRANITE IN THE VIRGINIA BLUE RIDGE. Matthew J. Heller and Roddy V. Amenta, Dept. of Geology and Geography, James Madison Univ., Harrisonburg, VA 22807. The Old Rag Granite is a pre-Cambrian formation in the core of the Blue Ridge Complex in Northern Virginia. At Old Rag Mountain the granite is coarse grained with large cream colored feldspar crystals and masses of blue quartz. The granite is associated with a series of pre-Cambrian gneisses but relationships are uncertain. An intrusive origin has been proposed for the granite but published radiometric dates suggest that it is older than the gneisses. Pegmatitic veins and dikes with mineral assemblages similar to that of the Old Rag granite are present within two of the gneissic formations, the Livingston gneiss and the Flint Hill gneiss. Our observations of field relationships and petrologic analyses of a small dike collected near Old Rag Mountain confirms the intrusive origin of the Old Rag granite into the gneisses.

BACTERIAL OXIDATION OF MN IN A STREAM ENVIRONMENT. Matthew J. Heller and Gene D. Robinson\*, Dept. of Geology and Geography, James Madison Univ., Harrisonburg, VA 22807. Dark coatings on stream pebbles are a common form of Mn-oxide precipitate. Although the origin of such coatings remains uncertain, Mn-oxidizing bacteria have been shown to be important in precipitating other types of surficial Mn deposits. Similarities between such deposits and stream pebble coatings led to an attempt to culture and isolate Mn-oxidizing bacteria from a small stream in Virginia. Two restrictive media were used to create environments favorable to Mn-tolerant microbes. The morphology and composition of colonies cultured from water samples and stream pebble coatings were investigated using a scanning electron microscope equipped with an energy dispersive X-ray analyzer. These analyses indicated the presence of two distinct colony types which precipitated dark Mn-oxide. The presence of Mn-oxidizing microorganisms in stream water and pebble coatings suggests that they play an important role in the formation of such deposits.

THE HISTORY OF VIRGINIA'S GEOLOGICAL SURVEY. Stanley S. Johnson\*, Department of Mines, Minerals and Energy, Division of Mineral Resources, Charlottesville, VA 22903. The Division of Mineral Resources has undergone three previous organizational names (Geological Survey of Virginia, 1835-43; Virginia Geological Survey, 1908-54; Division of Geology, 1954-57) and has been directed by seven state geologists since its inception in 1835 (W.B. Rogers, 1835-43; T.L. Watson, 1908-24; W.A. Nelson, 1925-28; A.C. Bevan, 1929-47; W.M McGill, 1947-57; J.L. Calver, 1957-78; R.C. Milici, 1979-91). The Division was the fifth legislatively formed state survey in the United States. On March 6, 1835, "An Act to Authorize a Geological Reconnaissance of the State with a View to the Chemical Composition of its Soils, Minerals and Mineral Waters" was passed by the Legislature. William Barton Rogers was appointed to direct this new organization and was the first "State Geologist" of Virginia. Since the first report by Rogers on the mineral resources in Virginia in 1836 (Report of the Geological Reconnaissance of the State of Virginia), the succeeding surveys have amassed a large amount of data regarding Virginia's geology and mineral resources. These data have been presented in more than 300 published reports and articles.

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AN INTRODUCTION TO THE ROCKFALL HAZARD RATING SYSTEM Todd A. LaMaskin, Ted A. Witteman, and C.F. Watts, Dept. of Geology and Inst. for Engineering Geosciences, Radford Univ., Radford, VA. 24142. The Rockfall Hazard Rating System (RHRS) was developed by the Oregon Department of Transportation to evaluate potential hazards on roadcut slopes. It is intended to give highway departments a list of potentially hazardous rockslopes which are ranked in order of potential danger. Upon measurements and inspection, points are assigned in ten categories. Point totals are used to rank rockslopes relative to one another. Highway departments can use this ranking to determine where they should place the most remediation effort. The system does not determine what slopes are most likely to fail, but those that are most likely to cause potential damage if they do fail.

RE-EVALUATION OF THE AGE OF TRIASSIC STRATA (DOSWELL FORMATION) OF THE TAYLORSVILLE BASIN, VA. Ronald J. Litwin\*, MS 970, U.S. Geological Survey, Reston, VA 22092, & Robert E. Weems, MS 928, U.S.G.S., Reston, VA 22092. Rocks of the Doswell Formation (Taylorsville basin, VA) have been assigned variously to the lower Carnian, middle Carnian, and/or upper Carnian (Upper Triassic) on the basis of micropaleontological evidence (palynology). As such, the rocks in this basin have been accepted to be some of the oldest in the Newark Supergroup. Two differing stratigraphic interpretations have been proposed for these strata. The older interpretation is predicated on fault repetition of the lower strata in the basin, and the more recent interpretation views these same units as intertonguing and diachronous lithologic members. Recent reexamination of two palynological samples- one from the Newfound Member (R4353, Ashland No. 1 core) and one from the Falling Creek Member (R4429, Stagg Creek locality)- have enabled us to test these two hypotheses on the basis of palynological evidence. Sample R4353 contains *Camerospores verrucosus*, *Gordonispora fossulata*, *Kyrtomisporis speciosus*, *Minutoscoccus crenulatus*, *Praecirculina granifer*, and *Pseudenzonaspores summus*, yielding the first early Norian palynological assemblage reported for the Doswell Formation. This establishes that the Newfound Member is at least in part lower Norian, and therefore is correlative to the upper part of the Manassas Sandstone (Culpeper Group, Culpeper basin, VA). If the laterally intertonguing interpretation were correct, sample R4429 should be stratigraphically higher, and thus should contain a still younger (early to middle Norian) assemblage. However, sample R4429 contains *Alisporites opii*, *Brodipora striata*, *Camerospores secatus*, *Cycadopites stonei*(?), *Lagenella martini*, *Patinaspores densus*, and *Trilites klausii*, indicating an older, late Carnian age. The palynological evidence from these samples therefore is consistent with fault repetition, but inconsistent with the postulated lateral intertonguing.

GRADIENT INCREASES AND SINUOSITY ADJUSTMENTS ON A SINKING STREAM, GREENBRIAR COUNTY, WEST VIRGINIA. Steve Marshall\* and G. Richard Whittecar, Dept. of Geol. Sci., Old Dominion Univ., Norfolk, Va. 23529. Cove Creek, a disappearing stream in a spectacular blind valley in Maxwelton, W.V., gradually increases in sinuosity from nearly straight ( $P=1.12$ ) to sinuous ( $P=1.80$ ) in the 200 meters upstream of its sink. Throughout that reach, average radii of curvature of channel meanders decrease and the gradient of the valley steepens. Along the 300 meters upstream of the sink, sediments that comprise the perimeter of the channel vary widely in mud content (33-71%) and display no downstream trend in texture. Average channel gradients through the zone of increasing sinuosity are the same as those upstream. These observations indicate that the changing sinuosity in this stream is not controlled by bank sediment texture. Instead, Cove Creek has maintained its geomorphic equilibrium by increasing its sinuosity during periodic episodes of base level lowering.

FLUVIAL TERRACE DEVELOPMENT ON NORTH RIVER NEAR WEYERS CAVE, VA. Roger C. Nelson and W. Cullen Sherwood, Dept. of Geol. and Geog., James Madison Univ., Harrisonburg, VA 22807. An investigation of the North River terraces near Weyers Cave, Va., included field surveying and coarse sediment analyses of 137 samples of alluvium from 13 boreholes. Sand and gravel fractions showed significant terrace-to-terrace variations. The alluvium of the lower terrace measured approximately 3.8 m in depth, was comprised mainly of fine sand (65%) with virtually no gravel, and exhibited an overall coarsening upward trend. The middle terrace alluvium yielded a maximum thickness of 3.2 m. Sand plus gravel averaged 29% with a weak coarsening upward trend and local concentrations of gravel. Maximum depth of the upper terrace alluvium was 4.3 m. Sand plus gravel was 53% with a fining upward trend. The depositional history of the terrace is interpreted as follows: 1) Downcutting and north lateral migration of North River has resulted in the formation of 3 well developed unpaired terraces along the south bank, 2) Overbank flow appears to be the principal mode of deposition, 3) Minor point bar accretion is indicated in the middle terrace, and 4) Significant differences in sand and gravel content throughout the sequence indicate that the texture of the sediment delivered by the river varied significantly over time.

THE BEREAL SANDSTONE- A SHALLOW, LOW PERMEABLE GAS RESERVOIR IN DICKENSON COUNTY, VIRGINIA. Nolde, Jack E., Virginia Dept. of Mines, Minerals and Energy, Division of Mineral Resources, Charlottesville, Virginia, 22903.

The Berea Sandstone is a major resource of natural gas in a low permeability, low pressure reservoir at depths of less than 5,000 feet in Dickenson County. The sandstone lies between the underlying Devonian shale sequence and the overlying Sunbury Shale. Thickness of the Berea ranges from 20 to 150 feet. Gas associated with the Berea is the product of the immature stage of hydrocarbon generation (biogenic gas).

Trend surface analysis of thickness data delineates a prominent nearshore bar complex and associated facies extending northerly across the central-portion of the county. These nearshore marine bar sediments are cut locally by shallow marine channel deposits of the Virginia-Carolina delta. The marine bar facies is a coarsening-upward sequence consisting of very-fine-grained sandstone. The channel facies grades upward from medium-to fine-grained sandstone. Porosity in these facies ranges from 2 to 5 percent, with permeabilities of 0.003-0.008 millidarcies.

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LEGAL AND ENVIRONMENTAL ASPECTS OF SEDIMENTATION. Robert C. Whisonant, Dept. of Geology, Radford Univ., Radford, Va. 24142; James D. Phillips,\* Office of the Attorney General, Supreme Court Building, Richmond, Va. 23219; Chester F. Watts, Inst. for Engineering Geosciences, Radford Univ., Radford, Va. 24142. Geologists, engineers, and the Commonwealth of Virginia commonly interact concerning the legal and environmental aspects of sedimentation. For example, the Code of Virginia has several sections devoted to erosion and sediment control law in relation to land-disturbing activities, an area where geologists and engineers typically interface. In addition, the Virginia Erosion and Sediment Control Handbook is significant in that it delineates the Commonwealth's approved techniques for controlling the impact of sediment upon the environment. Of great interest to geologists and engineers working with the environmental aspects of sedimentation are methods designed to estimate the quantity of sediment or runoff produced in a certain area. We review both pros and cons of two of the most widely used techniques, the Universal Soil Loss Equation and the Rational Method of calculating runoff. Virginia courts have adopted the traditional rule of riparian rights which provides that legal responsibility will issue to a property owner who causes or allows matter to enter a stream of water which "...renders the water less wholesome..." in a material and substantial way from its natural state. Although there are no reported Virginia decisions which specifically address the issue of liability for sedimentation, it is suggested that the analysis of such a question will result in a similar resolution.

EXAMPLES OF THE APPLICATION OF THE ROCKFALL HAZARD RATING SYSTEM TO VIRGINIA HIGHWAYS Ted A. Wittemann, Todd A. LaMaskin, and C.F. Watts, Dept. of Geology and Inst. of Engineering Geosciences, Radford Univ., Radford, VA. 24142. The Rockfall Hazard Rating System (RHRS) was applied to four roadcuts along Route 100 in Giles County, Virginia. The roadcuts expose Cambrian and Ordovician age carbonate rock, which is faulted and highly fractured. The criteria used in choosing the roadcuts for study included diversity in structural discontinuities and bedding plane attitude. Using the the RHRS, an assessment of each site was made and scores were assigned. Of the four roadcuts studied, one was determined to have relatively high rockfall hazard potential, two were classified as moderately hazardous and one was found to be of little or no potential hazard. In the weeks following this study, failure occurred on the roadcut that was considered to be of little or no hazard. This failure was fully contained in the catchment and presented no danger to motorists.

## Materials Science

CHEMICAL REACTIONS IN THE NUMERICAL MODELING OF InP MOCVD. Linda R. Black, NASA Langley Res. Ctr., MS 473, Hampton, VA 23665. The role of chemical reactions in the modeling of metalorganic chemical vapor deposition (MOCVD) of InP was examined. A reactor with a rectangular flow channel and a tilted rf-heated susceptor was used in this study. InP thin films were deposited on fused-silica substrates from trimethylindium and phosphine precursor materials entrained in a hydrogen carrier gas at reactor operating pressures of 0.1 and 1.0 atm. The process was modeled numerically using a commercially available computational fluid dynamics code. Equations for the conservation of mass, momentum, energy and chemical species were solved by a finite difference method over a 2-D nonuniform rectangular grid. A simplified chemical reaction scheme involving three reactions was incorporated in the model. Predicted and experimentally determined deposition rate profiles were compared. It was found that it was necessary to modify the pre-exponential term of the Arrhenius reaction rate expression for the surface reactions to obtain good agreement between the model and experiment at both 1.0 and 0.1 atm operating pressure. Details of this modification will be presented along with predicted and experimentally determined growth rate profiles.

CHARACTERIZATION AND KINETIC RESPONSES OF REACTIONS IN TITANIUM ALUMINIDE MATRIX COMPOSITES. P. Cantonwine, L. Hsiung, and H.N.G. Wadley, Dept. of Material Science, Thornton Hall, University of Virginia, Charlottesville, VA 22903-2442. Single crystal  $\text{Al}_2\text{O}_3$  fibers are being investigated as a possible reinforcement material in titanium aluminide composites. Since  $\text{Al}_2\text{O}_3$  is in general thermodynamically incompatible with titanium aluminides, it is important to understand the subsequent reactions. This study is concerned with characterizing the morphology and kinetics of reactions in a  $\text{Al}_2\text{O}_3$ / Ti 24% Al 11% Nb (at%) metal matrix composites. TEM studies indicate a multilayered reaction zone. An amorphous titanium oxide layer with pockets of crystalline regions is observed at the fiber/reaction interface. The second layer appears to be gamma TiAl. The kinetic study indicated the  $\text{Al}_2\text{O}_3$  fibers had a lower activation energy and a higher reaction rate than the standard SCS-6 (SiC) fibers.

THE CRYSTAL STRUCTURE OF {111} PRECIPITATES IN AN Al-Cu-Mg-Ag ALLOY. Y. C. Chang and J. M. Howe, the Department of Materials Science and Engineering, School of Engineering and Applied Science, University of Virginia, Charlottesville, VA 22903.

The structure of {111} precipitates in Al-Cu-Mg-Ag alloys has been extensively studied and the results are controversial. Several structure models have been proposed: monoclinic, hexagonal, orthorhombic ( $\Omega$ ) and tetragonal ( $\theta_M$ ). In this study, XRD, TEM/SAD and HRTEM were employed to analyze the structure of {111} precipitates in an Al-3.9Cu-0.5Mg-0.5Ag (wt.%) alloy in various heat-treated conditions. The XRD analysis showed that the lattice spacings and intensities of the {111} precipitates are identical to those of the  $\theta$ - $\text{Al}_2\text{Cu}$  phase in a binary Al-4 wt.% Cu alloy, so that the {111} precipitates are a variant of  $\theta$ . HRTEM image simulations indicate that all of the three structure models of  $\Omega$ ,  $\theta$  and  $\theta_M$  appear similar and can account for experimental HRTEM images under typical imaging conditions. A detailed analysis of SAD patterns containing {111} precipitates showed that: (a) {111} precipitates have lattice parameters which are slightly less in  $a$  and  $b$  and slightly larger in  $c$  than those proposed for the  $\Omega$  structure, (b) the hexagonal structure cannot account for the SAD patterns, and (c) all of the extra reflections typical found in SAD patterns from other than the {111} precipitates can be explained as due to other precipitates or double diffraction involving the matrix and precipitates. (Supported by the National Science Foundation under grant DMR-9107550.)

THE CORROSION PERFORMANCE OF INCONEL 625 WELDMENTS WITHIN A FRESH WATER COOLING SYSTEM. D.G. Enos and S.R. Taylor, Dept. of Materials Science, Thornton Hall, University of Virginia, Charlottesville, VA 22903. Commercial power generation plants frequently experience extensive corrosion problems within their service water systems. The corrosion mechanism involved has been identified as a combination of both general as well as microbiologically induced corrosion (MIC). An appropriate solution to this problem is the substitution of a more corrosion resistant material in place of the currently applied steel piping. The focus of this project is to evaluate such a solution, in this case a low carbon steel pipe with an internal cladding of Inconel 625, a highly corrosion resistant, nickel based alloy. Of particular interest will be the behavior of the material around weldments throughout the system. Due to the non-equilibrium solidification nature of weldments, the actual material properties within the weld may be different than expected within the base material due to solute segregation, second phase precipitation, or, in the case of this clad material, dilution within the weldments. Issues which will be addressed include the susceptibility of the new material to MIC as well as its resistance to general corrosion. (Supported by Virginia Power and the Center for Innovative Technology of the Commonwealth of Virginia)

INVESTIGATION OF THE EFFECT OF THERMAL EXPOSURE ON THE MECHANICAL PROPERTIES OF Ti-1100/SCS-6 COMPOSITES. Douglas B. Gundel, F.E. Wawner, Dept. of Materials Science and Engineering, Univ. of Va., Charlottesville, VA 22903. Titanium-matrix, silicon carbide fiber-reinforced composites are promising candidates for future high temperature aerospace applications. The effect of cyclic thermal exposure on the tensile properties of Ti-1100/SCS-6 composites was investigated. The material was cycled from 150°C to 700 and 800°C in air and in an inert environment then tensile tested to note any property degradation. The cycled samples were analyzed to correlate property loss to microstructural changes of the matrix, fibers, or interface. Fractographic studies indicate that the matrix is greatly affected by the cycling in air to 800°C and this seems to be a prime contributor to the composite degradation. The accumulated damage in the composite is most probably due to the combined effect of residual thermal stresses and high temperature environmental interaction (oxidation).

HYDROGEN ENVIRONMENT EMBRITTLEMENT OF BETA TITANIUM ALLOYS. Lisa M. Hartman, Dept. of Materials Science, Univ. of Virginia, Charlottesville, Va. 22903. The hydrogen environment assisted cracking (HEAC) resistance of two peak aged metastable  $\beta$ -titanium alloys, Beta 21S and Ti-15-3, is characterized by a fracture mechanics resistance-curve method. Rising load tests with an aqueous 3.5% NaCl environment show that Beta 21S is susceptible to HEAC. Relative to a moist air crack initiation toughness ( $K_{IC}$ ) of 67 MPa $\sqrt{m}$ , the threshold for stable crack growth ( $K_{th}$ ) in chloride is as low as 38 MPa $\sqrt{m}$  and fracture occurs by intergranular separation. The magnitude of the reduction from  $K_{IC}$  to  $K_{th}$  depends on dynamic loading rate; for Beta 21S,  $K_{th}$  is a minimum at an intermediate crack tip strain rate of order  $10^5$  sec $^{-1}$ . In contrast the initiation fracture toughness of Ti-15-3 in moist air is lower (59 MPa $\sqrt{m}$ ) than that of Beta 21S, but is unaffected by exposure to NaCl at several constant loading rates. HEAC is also not produced in Ti-15-3 by either constant load exposure or by a high frequency low amplitude ripple load designed to rupture the crack surface passive film without inducing process zone volume fatigue damage. The difference in the HEAC resistance of the two alloys is attributed to higher yield strength and abundant  $\alpha$  precipitation on  $\beta$  grain boundaries in the Beta 21S. (Supported by the Office of Naval Research and the Virginia CIT.)

NUMERICAL THERMAL ANALYSIS OF A SAMPLE OF GERMANIUM WITH A CENTERLINE CAPILLARY TUBE IN A VERTICAL BRIDGMAN FURNACE. James A. Hubert, Air Force Liaison Office, Langley Research Center (NASA) M.S. 221, Hampton, VA 23665, Archibald L. Fripp, Langley Research Center (NASA) M.S. 473, & Christopher S. Welch\*, Langley Research Center (NASA) M.S. 231. Thermal radiation analysis and finite difference computer programs were used to find the temperature distribution in a quartz ampule containing high purity germanium in a vertical Bridgman furnace. Data was taken from experiments designed to correlate thermocouple temperature readings with crystal growth using x-ray imaging to monitor the growth. The ampule was fitted with a capillary tube along its centerline which was used for insertion of thermocouples to measure temperature profiles in the solid-liquid interface region. Results of the capillary measurements exposed a shift of 3—4 mm in the thermocouple measured interface location (location of the change in slope of temperature) compared to the x-ray indicated location. Since no explanation was uncovered for this shift, a detailed thermal model was generated and used to study the problem. The shift in the temperature indicated interface location was predicted by the computer model. Further analysis showed that this shift is due to an end-effect in the thermocouple due to conduction of heat away from the tip. This end-effect causes a spatial translation of the measured temperature profile.

CREVICE CORROSION OF ALLOY 625 IN CHLORINATED ASTM SEAWATER. Michael P. Jurinski and John R. Scully, Center for Electrochemical Sciences & Engineering, Department of Materials Science & Engineering, University of Virginia Charlottesville, VA 22903. Alloy 625 is known to be susceptible to crevice corrosion in seawater environments. In the present study factors controlling initiation and propagation have been explored. The literature reports that crevice corrosion initiation requires a critical IR drop. Results presented here indicate that once this critical IR drop is exceeded, crevice corrosion propagation is also IR controlled. The potential required to suppress crevice corrosion propagation has also been determined for the conditions investigated. This potential is shown to correspond to the open circuit potential of the active crevice. Concerning the effects of solution alterations, chlorination is shown to decrease the time required for initiation. Addition of molybdate to the solution has proven to be beneficial in both suppressing initiation and reducing propagation rates. Mixed potential theory and the thermodynamics associated with Mo oxidation are used to explain the results observed. Insight into the metal cation concentrations associated with crevice chemistries is being investigated.

EXPERIMENTAL DESIGN TECHNIQUES IN MATERIALS SCIENCE. Sudesh Kannan, Dept. of Materials Science, Univ. of Va., Charlottesville, VA 22903. Design of experiments involves the efficient use of resources in studying a large number of variables with a minimum number of trials. Factorial designs are experiments that involve  $n$  variables at two levels. These designs consist of  $2^n$  runs. In addition to determining the effect of each variable, it is also possible to find the effect of interactions between variables. A wide range of designs for experiments are available - for example Plackett-Burman screening designs are very useful when the investigator is working on the initial set of experiments to determine the significant variables for study. Combined with basic statistics, experimental design techniques are very powerful tools for the experimenter.

FLOW ORIENTATION OF NATURAL CONVECTION IN VERTICAL BRIDGMAN CONFIGURATION USING SOLID STATE ELECTROLYTE. Keryih Kao, R. Narayanan\*, T. J. Anderson\*, Dept. of Chem. Engr., Univ. of Florida, Gainesville, FL 32611, & A. L. Fripp, W. Debnam\*, G. Woodell\*, NASA, Langley Res. Ctr., MS 473, Hampton, VA 23665. An electrochemical technique using solid state electrolytes to determine the natural convection flow orientation in vertical Bridgman configuration is being developed and tested. Liquid tin and oxygen element are used as model fluid and tracer. Solid state electrolyte yttria-stabilized zirconia as part of the ampoule is being used to implant and detect oxygen tracers on the boundaries. The detections of oxygen on the ampoule boundaries will be used to interpret the flow orientation. Preliminary experiments of oxygen diffusivities in liquid tin as a function of temperatures are performed. The measured diffusivities compared with other researchers' values reveal that in a less well controlled experiment, oxygen transport is conveyed by diffusion and natural convection.

PASSIVITY OF HIGH STRENGTH TITANIUM ALLOYS. D.G. Kolman and J.R. Scully\*, Dept. of Materials Science, University of Virginia, Charlottesville, VA, 22903.

$\beta$ -titanium alloys such as  $\beta$ -21S and Ti-15-3 have been proposed as high strength materials for use in marine environments. However, susceptibility to environmentally assisted cracking (EAC) has been indicated for  $\beta$ -21S under certain conditions (L. Hartman and R.P. Gangloff, University of Virginia). It is of interest, therefore, to examine both the nature of the passive film and the repassivation behavior of the  $\beta$ -titanium alloys in order to elucidate the EAC mechanism. As an initial step in this investigation, the anodic electrochemical behavior of the alloys has been examined utilizing both AC and DC methods. A matrix of experiments was performed wherein the solutionized and peak aged conditions of the  $\beta$ -titanium alloys have been examined in different solutions.

CIRCUIT FITTING OF ELECTRICAL CIRCUIT ANALOGUES IN EIS. Kevin C. Stewart\* and S.R. Taylor, Department of Materials Science and Engineering, Thornton Hall, University of Virginia, Charlottesville, VA 22903-2442. Electrochemical Impedance Spectroscopy (EIS), is an experimental technique that measures the frequency-dependent relationship between the potential and current across a metal-solution interface. One way of representing the physical processes on the surface is to interpret that voltage/current relationship as the impedance of an equivalent circuit. Knowledge about the values of the elements in that circuit yields information about the surface. There are three principle ways of getting estimates for the values of the circuit elements from an impedance scan. They can be extrapolated from a graph, produced by fitting to a polynomial expression for the impedance, or found by fitting to a matrix expression for the impedance. Each technique has its own underlying assumptions, advantages and limitations. The matrix method of determining impedance in particular has the great advantage of allowing nearly any circuit model including ladder networks to be used.

ELEVATED TEMPERATURE FRACTURE TOUGHNESS OF A SiC PARTICULATE REINFORCED 2009 ALUMINUM COMPOSITE. B. Somerday, Dept. of Materials Science, Thornton Hall, Univ. of Va., Charlottesville, VA 22903. The fracture toughness of an Al/SiC<sub>p</sub> composite is characterized from 25 to 316°C.  $K_{IC}$  mildly increases through a maximum at 220°C and a transition from unstable crack growth to stable tearing occurs near 200°C. The fracture mode is based on localized matrix plasticity that produces shallow dimples at each temperature. Micromechanical modeling based on the critical strain concept qualitatively predicts the temperature dependence of  $K_{IC}$  and the onset of stable tearing.

X-RAY PHOTOELECTRON SPECTROSCOPIC (XPS) ANALYSIS OF MATERIALS FROM THE NASA-LDEF SATELLITE. J. W. Chin, T. F. Cromer, H. L. Grammer, H. F. Webster & J. P. Wightman, Dept. of Chemistry, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061 and P. R. Young, Materials Division, NASA-LARC, Hampton VA, 23665. The recovery of the NASA-LDEF satellite after nearly six years in low earth orbit presented an unprecedented opportunity to study the effect of the space environment on a variety of materials. Silvered fluorinated ethylene propylene (FEP) polymeric films underwent marked changes in reflectivity depending on their location on the satellite. FEP films located on the trailing edge of LDEF where exposure to atomic oxygen was minimal remained specularly reflective. However, FEP films located on the leading edge with maximum exposure to atomic oxygen were opaque. This change in reflectivity was not due to expected changes in surface composition as shown unequivocally by XPS. The change in reflectivity was shown to be due to changes in surface topography as observed readily by scanning electron microscopy. [Research supported by NASA-Langley Research Center]

THE EFFECTS OF HYDROGEN ON THE MECHANICAL PROPERTIES OF HIGH-STRENGTH TITANIUM ALLOYS. George A. Young Jr. and John R. Scully\*, Materials Science and Engineering, The University of Virginia, Charlottesville, VA 22903. The hydrogen embrittlement susceptibility of high strength beta titanium alloys (Ti-15V-3Cr-3Al-3Sn and Beta 21S Ti-15Mo-3Nb-3Al, wt%) is assessed as a function of hydrogen concentration and stress state. Both Bridgman-type notched tensile bars and elastic-plastic fracture mechanics experiments will be used to characterize hydrogen effects on mechanical properties. This work seeks to distinguish intrinsic from extrinsic (i.e. hydriding) effects of hydrogen. Moreover, Devanathan-Stachurski permeation experiments will be correlated to metallographic and fractographic features to assess the permeation and trapping behavior of hydrogen in these alloys. (Sponsored by the Office of Naval Research and the Commonwealth of Virginia, Center for Innovative Technology)

## Medical Science

THE DESIGN, SYNTHESIS AND STRUCTURE-AFFINITY RELATIONSHIPS OF NOVEL SIGMA RECEPTOR LIGANDS. S. Y. Ablordeppey\*, J. B. Fischer\*, R. A. Glennon, Dept. of Medicinal Chemistry, MCV/VCU, Richmond, VA 23298-0540. Evidence that several drug classes such as antipsychotic and antidepressant drugs bind to sigma receptors led to a tremendous growth in sigma receptor research. However, because of the limited knowledge of sigma receptor topography, and the lack of functional models of sigma receptor activation, progress in this area has been limited. To extend our understanding of sigma receptor topography and to obtain adequate knowledge of structure-affinity relationships, we have designed and synthesized several rather potent ( $K_i$  in subnanomolar range) and selective sigma ligands for pharmacological evaluation. Our research has provided additional information on structure-affinity relationship and led to a quantitative model (CoMFA) that explains the binding of various sigma receptor ligands. Further molecular modeling studies using the active analog approach provided additional support for some of the hypotheses emanating from the CoMFA model.

CYTOKINES AND TUMOR GROWTH INFLUENCES ON Ia<sup>-</sup> MACROPHAGE PRODUCTION OF TUMOR NECROSIS FACTOR- $\alpha$ . D.G. Alleva and K.D. Elgert. Dept. of Biology, Microbiology & Immunology Section, Va Polytechnic Inst. & State Univ., Blacksburg, VA 24061. Macrophages (M $\phi$ ) produce the tumor-killing molecule, tumor necrosis factor- $\alpha$  (TNF- $\alpha$ ) in response to growing tumors. TNF- $\alpha$  not only kills tumor cells but also regulates the action of immune cells. Studies show that TNF- $\alpha$  in an autocrine manner causes M $\phi$  to produce the immunosuppressive molecule PGE<sub>2</sub>; PGE<sub>2</sub> inhibits T-cell responses to cancer. This immunoregulatory characteristic of TNF- $\alpha$  suggests that TNF- $\alpha$ , aside from its tumor-killing action, may also cause suppression of anti-cancer responses. These two TNF- $\alpha$  functions may explain why the Ia<sup>-</sup> M $\phi$  subpopulation mediates both cytotoxicity of tumor cells and suppression of immune responses. By blocking PGE<sub>2</sub> or TNF- $\alpha$  production during tumor growth, we show that Ia<sup>-</sup> M $\phi$  are the suppressor population by increasing their PGE<sub>2</sub> and TNF- $\alpha$  production. Results of M $\phi$  culturing studies showed that Ia<sup>+</sup>-depleted (Ia<sup>-</sup>) normal host (NH) or tumor-bearing host (TBH) M $\phi$ , cultured with lipopolysaccharide (LPS), produced more TNF- $\alpha$  than their unseparated (Ia<sup>+</sup>-enriched) M $\phi$  counterpart. Also, TBH Ia<sup>-</sup> M $\phi$  produced significantly more TNF- $\alpha$  than NH Ia<sup>-</sup> M $\phi$  in response to LPS, LPS and interferon- $\gamma$ , or LPS and granulocyte-macrophage colony-stimulating factor. By determining that Ia<sup>-</sup> M $\phi$  are the main TNF- $\alpha$  producing cell population during tumor growth, perhaps the production and action of TNF- $\alpha$  may be better regulated during immunotherapy of cancer patients.

EXPRESSION OF Ia mRNA IN TUMOR-BEARING HOST MACROPHAGES: EFFECTS OF TUMOR NECROSIS FACTOR- $\alpha$ , LIPOPOLYSACCHARIDE, AND PROSTAGLANDIN E<sub>2</sub> ON INTERFERON- $\gamma$  INDUCTION. D. Askew and K.D. Elgert. Dept. of Biology, Microbiology & Immunology Section, Va Polytechnic Inst. & State Univ., Blacksburg, VA 24061. During tumor growth there is a dramatic decrease in Class II (Ia) expression in macrophages (M $\phi$ ), which corresponds to an increase in immunosuppression. Recent work in our laboratory has identified Ia<sup>-</sup> M $\phi$  as a major suppressor cell, and that tumor growth causes an increase in the number and suppressive ability of Ia<sup>-</sup> M $\phi$ . The regulation of Ia expression may prove to be a key component of tumor-induced immunosuppression. To determine the mechanisms of Ia expression, normal host (NH) and tumor-bearing host (TBH) M $\phi$  were cultured in the presence of interferon- $\gamma$  (IFN- $\gamma$ ), a potent inducer of Ia, and factors known to suppress Ia expression in NH M $\phi$  (such as lipopolysaccharide [LPS], and tumor-necrosis factor- $\alpha$  [TNF- $\alpha$ ]). Culturing M $\phi$  for 8, 16, and 24 hr showed that there is a decrease in the response of TBH M $\phi$  to IFN- $\gamma$ -induced Ia expression. Culturing of IFN- $\gamma$ -treated M $\phi$  in the presence of LPS showed greater suppression of Ia expression in TBH. LPS-induced suppression is due to increased prostaglandin E<sub>2</sub> (PGE<sub>2</sub>) production, as indomethacin treatment increased Ia expression. Another factor known to induce PGE<sub>2</sub> production in M $\phi$  is TNF- $\alpha$ . The addition of TNF- $\alpha$  suppressed Ia mRNA expression in NH M $\phi$ , but enhanced Ia expression in TBH M $\phi$ . The ability of TNF- $\alpha$  to enhance or suppress Ia expression depends on the maturation stage of M $\phi$ . TNF- $\alpha$  suppresses Ia induction in mature cells, but enhances its expression in immature cells. The down-regulation of Ia expression is caused by a combination of decreased responsiveness to enhancing factors and increased responsiveness to suppressing agents. (Supported by a Sigma Xi Grant)

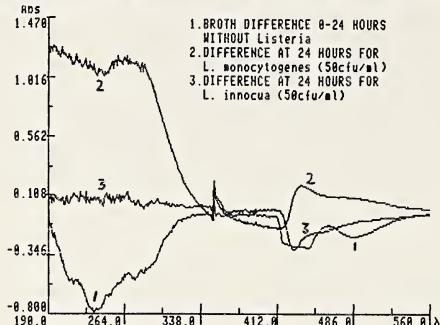
USE OF A HIGH VISCOSITY GROWTH MEDIUM FOR THE PRODUCTION OF SHEAR STRESS ON ADHESION-DEPENDENT CELLS. Anne Bradshaw, Andrea Feeback and Stephen Gallik, Department of Biological Sciences, Mary Washington College, Fredericksburg, VA 22401. A perfusion system is being designed for the study of the effects of flow-generated shear stress on adhesion-dependent cells. The system consists of a cell-lined, large-bore, round glass tube acting as the flow chamber and entrance and exit reservoirs designed to reduce hydrodynamic entrance and exit effects. The system depends on a high-viscosity flow medium to generate physiologically relevant intensities of shear stress. The capacity of this system to convey a laminar flows of fluids of various viscosities (0.8 to 120 centipoise) through the tube and thereby produce calculable shear stresses on the surface of the cells lining the tube has been determined at flow rates of 1 to 10 ml/sec. A tracer dye injected through a specially designed port located at the junction of the entrance reservoir and the glass tube was used to visualize the flow pattern. The visualized flow pattern was correlated with the calculated wall shear stress, Reynold's numbers and entrance length to determine those specific flow rates capable of delivering laminar flow.

VITAMIN C ANALYSIS IN HUMAN SERUM. R.B.Brandt, B.P.Dezzutti, J.Hsu and S.Falzone, Dept. of Biochem., Va. Commonwealth Univ., Richmond, VA 23298. Vitamin C (ascorbic acid) is a water-soluble vitamin that is required as both a co-factor for enzymatic activity and as an antioxidant. A modification of the spectrophotometric assay of Okamura (*Clin Chim Acta* 103:259(1980) using  $\alpha,\alpha'$ -dipyridyl was used to determine serum vitamin C. One ml of serum was deproteinized and acidified with meta phosphate. The supernatant fluid is used for assay where the color development is dependent on vitamin C reduction of ferric ion, which then chelates with  $\alpha,\alpha'$  dipyridyl. In subjects before and during vitamin C supplementation, the initial serum vitamin C was 1.2 mg/dL and increased to 2.2 mg/dL by ingestion of 1g/day for 2 months. The method is rapid, convenient and is not interfered with by common serum components. (Supported by NIH grant R01DE09523, NIH Cancer Education grant 5R25CA22032 and Hoffmann-LaRoche, Inc., Nutley, NJ.)

EFFECTS OF THERMAL AND PROTEOLYTIC ACTION ON LACTATE DEHYDROGENASE ISOZYMES. Gerald W. Capps, E. S. Kline & R. B. Brandt. Dept. of Biochemistry, Med. Col. Va., Va. Commonwealth Univ., Richmond, Va. 23298. L-Lactate dehydrogenase (LD) catalyzes the interconversion of pyruvate and lactate. Using a spectrophotometric assay to determine LD activity, incubation of rabbit, porcine, and bovine LD-1 and LD-5 isozymes with the protease subtilisin (Carlsberg) gave first-order degradation kinetics. Degradation half-lives were significantly lower for the LD-5 isozymes from the three species when incubated with subtilisin at temperatures from 4-25°C. The energy involved in the degradation process, however, was not different. The activation energy for the conversion of pyruvate to lactate by LD-1 at pH 7.4 was significantly higher than that for LD-5 for all three species examined ( $P < 0.005$ ). Thermocalorimetry showed that the LD-1 isozymes have both a higher mean temperature of denaturation and a higher heat uptake during the denaturation process than corresponding LD-5 forms. The results suggest that the LD-5 isozymes in the species studied are more metabolically efficient, while the LD-1 forms have greater structural stability. Supported by American Cancer Society's Tapan Hazra Memorial Research Fellowship and the Blanton Fund.

ALTERATIONS OF BEHAVIORAL LATERALIZATION AND REGIONAL BRAIN WEIGHTS IN NEONATAL RATS FOLLOWING EXPOSURE TO STRESS, IN UTERO. D.B. Carr\*, J. Wellman\*, A. Graham\*, <sup>1</sup>K. G. Lambert & C.H. Kinsley, Dept. Psychol., Univ. of Richmond, Va. 23173 & <sup>1</sup>Dept. Psychol., Randolph-Macon College, Ashland, Va. 23005. Prenatal stress (PS) disrupts sexual differentiation and possibly, owing to a dependence on certain prenatal factors, lateralization and asymmetry. Stressed pups (thrice-daily exposures to heat, light and restraint, E14-E21) and non-stressed controls were tested for 3 days (days P1-P3) for tail bias using degree of tail deviation ( $0^\circ$ - $360^\circ$ ) as the dependent measure. PS altered tail bias ( $172^\circ$  v.  $184^\circ$  for controls). On P4, pups were killed, brains removed, and midsaggital and coronal cuts were made to separate and weigh cortex-dienccephalon (C-D) and pons-medulla (P-M). PS resulted in heavier total brain weight, right hemisphere, and total C-D, whereas controls had a heavier left P-M. In summary, PS alters behavioral lateralization and gross brain asymmetry. Hence, PS effects may be due to changes in asymmetric brain activities.

SPECTRAL DIFFERENCES OF LISTERIA SPECIES: SEPARATION OF THE HUMAN PATHOGEN L. MONOCYTOGENES, THE NON PATHOGEN L. INOCUA, AND THE ABSENCE OF L. MONOCYTOGENES, IN CRAB MEAT. Germille Colmano, H. Sutton, J. Melia, K. Lee, College of Veterinary Medicine, Virginia Polytechnic Institute, Blacksburg, VA 24061-0442. A data base of characteristic spectrophotometric fingerprints



for different species of Listeria were selected, to be used for their detection and separation. Their differences, shown graphically in the Figure, indicate to the feasibility not only of Listeria detection, but also to the capability of separation of pathogenic from non pathogenic species. Supported by an Animal Health and Disease grant.

NICOTINE-INDUCED ANTINOCICEPTION : MODULATION BY CALCIUM AGONIST AND ANTAGONISTS. M.I. Damaj & B.R. Martin, Dept. of Pharmacology/Toxicology, Virginia Commonwealth University/Medical College of Virginia, Richmond, VA 23298.

There is good evidence that nicotinic receptor activation results in an increase in intrasynaptosomal and intracellular calcium concentration. The aim of this study was to describe the effect of a calcium agonist (BAY K 8644) and some calcium antagonists on nicotine-induced antinociception in the mouse. Male ICR mice received in the first part of the experiment 0.75 mg/kg of ( $\pm$ ) BAY K 8644 10 min before treatment with nicotine (0.01, 0.02, 0.05, 0.3 and 1 mg/kg). In the second part mice received nifedipine, nimodipine and verapamil at different doses (2, 5 and 15 mg/kg, i.p.) 20 min before treatment with nicotine (1.5 mg/kg, s.c.). There were 12 animals in each group. The antinociceptive effect was measured by the tail-flick method. BAY K 8644 and the calcium antagonists alone had no effect in the tail flick test. On the other hand, BAY K 8644 enhanced the antinociceptive effect in mice by 5- to 20-fold. For example, nicotine (0.05 mg/kg) alone produced no significant effect (%MPE = 5%), whereas BAY K 8644 pretreatment increased this MPE to 74%. The calcium antagonists reduced the analgesic effect of nicotine in a dose-related manner especially for nifedipine and nimodipine. Verapamil at the doses of 5 and 15 mg/kg reduced the response of nicotine (1.5 mg/kg) from 72% to 43%. Nifedipine and nimodipine at the dose of 15 mg/kg reduced the activity to 10.6% and 22.1% respectively. These findings are consistent with the biochemical observations that calcium plays a role in the pharmacological actions of nicotine. (Supported by PHS grant #DA-05274.)

SYNTHESIS OF A PSEUDO-BOND PEPTIDE INHIBITOR OF ATRIAL GRANULE SERINE PROTEINASE. Ajit Damodaran & Robert B. Harris, Dept. Biochem. & Molec. Biophys., VCU, Richmond, VA 23298.

Atrial granule serine proteinase (AGSP), discovered in this laboratory, is likely to be the physiologically relevant processing enzyme of pro-atrial natriuretic factor (pro-ANF). The processing site within the pro-hormone has been mapped to A<sup>96</sup>PRSLRR<sup>102</sup>. Cleavage occurs exclusively at the Arg<sup>98</sup>-Ser<sup>99</sup> bond to release functional ANF. N(Ac)APR-CH<sub>2</sub>-NH-SLRR CONH<sub>2</sub> is proposed to be a potent reversible inhibitor of the enzyme which can be easily modified to be an affinity ligand. Thus, solution phase synthesis of the synthon, Boc-Arg(Tos)-Ψ-Ser(Ot-But)-COOH was accomplished followed by solid phase synthesis (Boc- protocols) which incorporated the synthon. The peptide was characterized and shown to be an inhibitor of AGSP and of a homologous enzyme isolated from small cell lung cancer tumor.

STUDIES ON PROLIFERATION AND DIFFERENTIATION USING A TRANSFECTED SCHWANN CELL LINE. P. De Deyne, G.H. De Vries\*, J.W. Bigbee. Dept. of Anatomy, \*Dept. of Biochem. & Molec. Biophys., Medical College of Virginia, Virginia Commonwealth University, Richmond, VA. 23298. Schwann Cells (SC), the glial cells of the PNS, display a proliferative phase during nervous system development, followed by a differentiation phase coinciding with myelin sheath formation. In addition, SC can recapitulate the cycle following nerve trauma. Currently we are investigating phenotypic changes, representative of those SC developmental changes, using a SC line (TSC) transfected with the SV40 large T gene. In response to a 48 hr. treatment of no serum/1 mM dbcAMP the cells lengthen their doubling time from  $24 \pm 2.5$  hrs. to  $69 \pm 6.5$  hrs; alter their morphology from pleiomorphic to process bearing and increase their immunoreactivity for *c-fos* in the nucleus. Immunocytochemistry however does not show the presence of antigens representative of a myelin phenotype. In contrast using a 18 BP oligodeoxynucleotide complementary to mRNA of large T in combination with the no serum/1mM dbcAMP treatment suggests a change in phenotypic expression in the TSC, which is representative of a myelin phenotype.

STRUCTURE-AFFINITY RELATIONSHIPS OF SPIPERONE: STRUCTURAL DETERMINANTS OF AFFINITY AND SELECTIVITY FOR 5-HT<sub>2</sub> RECEPTORS. J. De Los Angeles, M. Teitler, R.A. Glennon. Dept. Medicinal Chemistry. MCV/VCU. Richmond, VA. 23298-0540. 8-[3-(*p*-Fluorobenzoyl)propyl]-1-phenyl-1,3,8-triazaspiro[4.5]decan-3-one (spiperone) is a neuroleptic agent that possesses significant affinity for several populations of 5-HT (serotonin) receptor sites as well as dopamine receptors. Spiperone binds to 5-HT<sub>1A</sub> sites with moderate to high affinity and to 5-HT<sub>1C</sub> sites with somewhat lower affinity. On the other hand, spiperone is a potent 5-HT<sub>2</sub> antagonist and binds with correspondingly very high affinity to 5-HT<sub>2</sub> sites ( $K_i = 1$  nM). Structure affinity relationship (SAFIR) studies conducted in our laboratory reveal that the fluorobenzoylpropylamine segment of spiperone comprises the minimum binding pharmacophore with respect to 5-HT<sub>2</sub> receptors while 5-HT<sub>1A</sub> and 5-HT<sub>1C</sub> generally require the intact spiperone structure for any measurable affinity. The triazaspiro portion of the spiperone structure appears to serve only as an auxiliary group with little or no measurable affinity as an entity, yet substantially enhances the affinity of the primary pharmacophore. In addition, certain functional groups in the spiperone structure have varying degrees of importance with respect to affinity for these different 5-HT receptor sites.

S(-)PROPRANOLOL AS A DISCRIMINATIVE STIMULUS: GENERALIZATION TO COCAINE. M. Dukat,\* R. Young\* and R. A. Glennon. Department of Medicinal Chemistry, MCV/VCU, Richmond, VA 23298. Although propranolol is typically regarded as a  $\beta$ -adrenergic antagonist, S(-)propranolol (S-PRO) also behaves as a 5-HT1A antagonist, and we have shown that it is a 5-HT1B partial agonist. Because, to date, animals have not been successfully trained to discriminate a 5-HT1B agonist from vehicle (due to a lack of 5-HT1B-selective agonists), we explored the use S-PRO as a training drug. Male SD rats were trained to discriminate 5 mg/kg of S-PRO (ED<sub>50</sub> = 2.5 mg/kg) from saline. Stimulus generalization occurred with  $(\pm)$ PRO (ED<sub>50</sub> = 4.4 mg/kg), and with the non-selective 5-HT1B agonists TFMPP and RU 24969 (ED<sub>50</sub> = 0.5 and 0.3 mg/kg), but not to the 5-HT agonist 5-OMe DMT or the 5-HT releasing agent fenfluramine. The NE uptake inhibitor nisoxetine resulted in 67% drug-appropriate responding. Stimulus generalization also occurred with cocaine (ED<sub>50</sub> = 2.3 mg/kg). Conversely, cocaine-stimulus (training dose = 8 mg/kg; ED<sub>50</sub> = 2.6 mg/kg) generalization occurred with S-PRO (ED<sub>50</sub> = 9 mg/kg). These results suggest that S-PRO probably produces its stimulus effects primarily via a noradrenergic mechanism; however, a role for 5-HT can not be completely excluded.

**STRUCTURE-AFFINITY STUDIES ON ARYLPiperazines AS SEROTONERGIC AGENTS.** M. El-Bermawy, M. Teitler, and R. A. Glennon, Dept. of Medicinal Chemistry, MCV/VCU, Richmond, VA 23298-0540. NAN-190 is a postsynaptic 5-HT<sub>1A</sub> antagonist that binds at 5-HT<sub>1A</sub> receptors with high affinity ( $K_i = 0.6$  nM); it also at  $\alpha_1$ -adrenergic receptors with almost the same affinity ( $K_i = 0.8$  nM). We designed, synthesized and tested a series of NAN-190 derivatives in order to identify and eliminate the structural features responsible for the  $\alpha_1$ -adrenergic effect. We found that the phthalimido end can be replaced with a simple benzamido moiety, various substituted benzamides have little influence on affinity and selectivity, replacement of phthalimido moiety with alkyl amides results in improvement in selectivity but decreased 5-HT<sub>1A</sub> affinity, alkylamides that have groups branched at the  $\alpha$  position enhance 5-HT<sub>1A</sub> affinity, and finally, replacement of the phthalimido portion with large and bulky amide substituents provides analogs that not only have higher 5-HT<sub>1A</sub> affinity than NAN-190 but also more selectivity for 5-HT<sub>1A</sub> versus  $\alpha_1$ -adrenergic receptors. NBUMP (5-HT<sub>1A</sub>  $K_i = 0.1$  nM; 460-fold selectivity) is the highest affinity 5-HT<sub>1A</sub> ligand reported to date.

**DESIGN, SYNTHESIS AND BINDING STUDIES OF SOME NICOTINE ANALOGS AT CENTRAL NICOTINIC RECEPTORS.** S. FAHMY, A. MAAROUF, J.R. JAMES, J. ROSECRANS, B. MARTIN AND R.A. GLENNON. DEPT. OF MEDICINAL CHEMISTRY AND PHARMACOLOGY, MCV/VCU, RICHMOND, VA 23298-0540. Central nicotinic receptors may be involved in CNS disorders, such as Parkinson's and Alzheimer's disease. To date, there are no potent and selective nicotinic agonists except for nicotine itself. Research conducted in our laboratory has been directed towards determining the structure-affinity relationships of some nicotine analogs which serve as a prelude to design and synthesis of novel selective nicotinic agonists. We have synthesized a series of nicotine analogs examining three features of the nicotine molecule: the pyrrolidine ring, pyridine ring and the distance between the two nitrogen atoms, to investigate the structural requirements for nicotinic binding. The nicotinic receptor affinity of these analogs was determined in brain tissue homogenates from whole mouse brain (minus cerebellum) using [<sup>3</sup>H]nicotine as radioligand.

**CELLULAR RESPONSES TO HIGH VISCOSITY CULTURE MEDIA.** Andrea Feeback, Margaret van Wambeck\*, Anne Bradshaw, Laura Johnson\* and Stephen Gallik. Department of Biological Sciences, Mary Washington College, Fredericksburg, VA 22401. The effect of high viscosity culture media on the morphology and proliferation of rat visceral pleural mesothelial cells was studied as part of a long-term investigation of the effects of mechanical stress on cells. The cells were grown to confluence in the presence of one of five concentrations of either methylcellulose (MC) or polyvinylpyrrolidone (PVP) in DMEM/F12 cell culture medium. These modified cell culture media had viscosities ranging from 0.8 to 120 centipoise. Subconfluent and confluent cell circumference and two-dimensional surface area were determined through the computerized analysis of digitized images of microscopic fields. The cell number was determined on each of 5 days following seeding using hemocytometric methods. Throughout the range of viscosities of both MC and PVP supplemented culture media, subconfluent and confluent cell size was not significantly different from that of cells grown in control culture medium. Throughout the range of viscosities of both MC and PVP supplemented culture media, cells grew to confluence, however the rate of cell proliferation was inversely proportional to the viscosity of the culture medium. These data indicate that at least some cell types can be grown in cell culture media of high viscosity.

MECHANISTIC STUDIES OF MORPHINE-INDUCED SUPPRESSION OF NATURAL KILLER CELL ACTIVITY: GLUCOCORTICOIDS AND THE SYMPATHETIC NERVOUS SYSTEM(SNS), D.O. Freier and B.A. Fuchs\*, Department of Pharmacology and Toxicology, Box 613 MCV Station, Richmond VA. 23298.

Implantation of 8, 25 and 75 mg morphine pellets, for 48 hours, in female B6C3F1 mice, produced marked suppression of natural killer (NK) cell activity measured by <sup>51</sup>Chromium (Cr) release from Yac-1 tumor targets. A time course of the effect of the 75 mg pellet from 3 hours to 7 days showed that the suppression of NK cytotoxicity was greatest between 12 and 48 hours, with recovery of the cytotoxic activity by day 7. Using a biotinylated NK1.1 antibody followed by phycoerythrin-strepavidin, a decrease in number of NK cells present in spleen was observed. This suggests that part of the drop in splenic NK activity may be due to the loss of NK cells from the spleen. Naloxone was used to determine the involvement of an opiate receptor. Naloxone methiodide, which crosses the blood brain barrier at a very slow rate, was used to determine if the receptor was centrally or peripherally located. A 16 hour time point was used for these studies. Both glucocorticoids and agents of the SNS have been hypothesized to mediate the observed suppression induced by morphine. Mice were given RU486 (200 mg/kg) 1 hour before implantation of 75 mg morphine pellets. 12 hours after implantation splenocytes were assayed for NK cell activity. RU486 blocked the morphine pellet induced suppression of NK cell activity. The ability of RU486 to block the action of morphine induced suppression, suggests morphine induced NK cell suppression is glucocorticoid mediated. Chlorisondamine (20 mg/kg), a non-competitive ganglionic blocker, was given by I.P. injection 1 hour before 75 mg morphine pellet implantation. Chlorisondamine was unable to produce a blockade of morphine induced suppression of NK cell activity, suggesting the SNS is not involved. Supported by NIDA RO1DA07292 and T32DA07027.

ADULT IMMUNE SYSTEM STRUCTURAL AND FUNCTIONAL EFFECTS IN RATS FOLLOWING PRENATAL STRESS. A. Graham\*, J. Wellman\*, D. Carr\*, M.R. Flory\*, J. Jones\*, K. Chamberlain\* & C.H. Kinsley, Dept. Psychol., Univ. of Richmond, Va. 23173. Prenatal stress (PS), which disrupts sexual differentiation, may modify systems similarly reliant on prenatal development, chief among them, immune system. Stressed pups (thrice-daily exposures to heat, light and restraint, E14-E21) and non-stressed controls were used in a series of studies designed to examine gross immune function and potential. In Exp. 1, P1 pups were killed and body and thymus weights were recorded. PS increased the size of the thymus gland. In Exp. 2 we examined a functional index of the immune system, skin graft transplantation immunity. Adults were grafted with same-sex thoracic skin grafts from control donors, and latency to reject this homotypical graft (the graft had completely sloughed off the recipients' skin) was recorded. Overall, PS males had the longest overall latencies to reject the graft. The data suggest that PS, in addition to its many effects on behavior and physiology, may also deleteriously affect immunocompetence.

COMPARISON OF THE NEUROCHEMICAL EFFECTS OF COCAINE AND LOCAL ANESTHETICS. J. H. Graham, S. E. Robinson\*, & J. R. Pascua\*, Dept. of Pharmacology & Toxicology, Medical College of Virginia, VCU, Richmond, VA 23298-0613. The psychomotor stimulant cocaine is known to produce some of its abuse related effects through striatal, mesocortical and mesolimbic dopaminergic pathways in the brain (Roberts et al., 1980). Because cocaine is also an esteratic local anesthetic, we decided to compare *in vivo* the effects of the local anesthetics dimethocaine, procaine and lidocaine with those of cocaine on dopamine (DA) metabolism in the striatum (STR), nucleus accumbens (NAcc), and prefrontal cortex (PFC). Male Sprague-Dawley rats were injected i.p. with either cocaine (30 mg/kg), dimethocaine (27.8 mg/kg), procaine (44 mg/kg) or lidocaine (65 mg/kg) and then euthanized 10, 25, or 40 min after injection. Their brains were removed and DA and its metabolites dihydroxyphenylacetic acid (DOPAC) and 3-methoxytyramine (3-MT) were analyzed using HPLC and GC/MS. DOPAC reflects primarily intracellular DA metabolism and 3-MT reflects extracellular metabolism. Cocaine, dimethocaine and procaine all increased the 3-MT/DA ratio significantly in the STR, and both cocaine and procaine produced this same increase in the NAcc and in the PFC. Dimethocaine and procaine decreased the DOPAC/DA ratio significantly for the STR and the NAcc. These results are consistent with an increased extracellular presence of DA and indicate that esteratic local anesthetics can affect dopaminergic areas in a manner similar to cocaine. (Supported by NIDA grant DA-00490 & the Commonwealth of Va. Ctr. for Drug Abuse Research).

DISCRIMINATIVE STIMULUS EFFECTS OF NMDA ANTAGONISTS AND GABA<sub>a</sub> AGONISTS. Doreen M. Grech\* and Robert L. Balster, Dept. of Pharmacology and Toxicology, Virginia Commonwealth University, Richmond, VA 23298-0613. There is increasing evidence to suggest that NMDA antagonists and GABA agonists may produce similar behavioral effects despite site-specific receptor activation. The NMDA competitive antagonists (CPP and NPC 12626) substitute for pentobarbital (PB) in PB-trained rats and antagonize the NMDA discriminative stimulus (DS) in NMDA-trained rats. Pentobarbital, diazepam, the GABA<sub>a</sub> agonist, THIP and ethanol, all fail to block the NMDA DS. In PB-trained rats, diazepam fully substitutes for PB but the direct GABA<sub>a</sub> agonists muscimol and THIP produce DS effects which differ from PB. These results indicate differences in the behavioral effects of indirect and direct GABA<sub>a</sub> agonists exist comparable to that seen with competitive and noncompetitive NMDA antagonists. This suggest selective modulation of the NMDA and GABA<sub>a</sub> receptors may result in transduction mechanisms which produce similar behavioral effects in rodents. (Supported by NIDA grants DA 01442 and DA 07027).

CONDITIONING OF NUDE BONE MARROW INCREASES IN VITRO MIGRATION TO THYMUS SUPERNATANT. Andrew J. Hall, Jack L. Haar\*, Kevin R. McCormick\*, Hugh D. Massey\*, Dept. of Anatomy, Div. of Immunobiology, Med. Col. of Va., Va. Comm. Univ., Richmond, VA, 23298. The thymus is continuously seeded by cells termed prothymocytes emanating from the bone marrow. The ability of the body to distinguish self from non-self and mount a functionally mature immune response is dependent upon the intrathymic education of these cells. Therefore, it is apparent that successful migration of prothymocytes into the thymus is an unescapable event in the development and maintenance of the immune system. Utilization of the athymic Nude mouse is a valuable asset in the elucidation of the mechanisms influencing the migration of bone marrow cells into the thymus. Its aberration enables investigators to examine the effect of thymic factors on cells previously devoid of thymic influence. In an attempt to understand the normal migration of prothymocytes into the thymus, we analyzed the in vitro migration of athymic bone marrow cells towards newborn thymus supernatant. Adult athymic murine bone marrow cells were incubated in either thymus supernatant or media and allowed to migrate towards one or the other. Similar control experiments were performed using CBA adult mice. Results indicate that athymic bone marrow migration towards both supernatant and media can be restored to control levels after incubation in thymus supernatant.

EFFECT OF COCAINE AND OTHER LOCAL ANESTHETICS UPON EXTRACELLULAR STRIATAL DOPAMINE LEVELS AS DETERMINED BY *IN VIVO* MICRODIALYSIS. John Harms and John J. Woodward, Medical College of Virginia, Virginia Commonwealth University, Richmond, VA 23298-0613. The dopamine uptake transporter in neuronal presynaptic terminals appears to be important in mediating reinforcing behavior in animals, which is central to cocaine addiction. We studied the importance of the chemical structures of cocaine and other related local anesthetics through the use of synaptosomal uptake and *in vivo* microdialysis. Of the local anesthetics tested, only cocaine ( $IC_{50}$  0.6 uM) and dimethocaine ( $IC_{50}$  4 uM) fully inhibited synaptosomal uptake. Procaine, tetracaine, propoxycaine, and piperocaine only partially inhibited uptake at the highest concentration tested (100 uM). Lidocaine had no effect upon the uptake transporter. Based upon these results, only three of these compounds were selected to be tested using *in vivo* microdialysis. Cocaine and dimethocaine caused a dose dependent increase in the dopamine levels. At 100 uM cocaine and dimethocaine elevated the dopamine levels by approximately 30-fold and 5-fold respectively. Lidocaine did not stimulate any detectable increase even up to a concentration of 1 mM. These results suggest that there are clear structural differences between the local anesthetic actions of cocaine and its reinforcing addictive properties. (Supported by NIDA P50DA05274).

EFFECTS OF PRENATAL COCAINE EXPOSURE ON PITUITARY HORMONE PRODUCTION. Mark Jacobucci, Lauren McGurk, & Karen Oates, Ph.D. Dept. of Bio., George Mason Univ., Fairfax, VA 22030. The effects of prenatal cocaine exposure on immune suppression at the level of anterior pituitary hormone secretion were studied. Previous studies have shown cocaine exposure in adult animals inhibits cellular and humoral immune responses. Cocaine may decrease prolactin levels by increasing dopamine. Increases in dopamine have been shown to inhibit prolactin secretion. Prolactin levels were evaluated because a plausible mechanism linking prolactin to cocaine exists, and prolactin is known to enhance immune responses and to block immune suppression by glucocorticoids. Pituitary cells from day 21 Long-Evans Rats prenatally exposed to cocaine were cultured. Pituitary cell supes were collected, and radioimmunoassays were performed to determine the amount of prolactin and growth hormone secreted. Significantly less prolactin was secreted by the pairfed, 20 mg/kg, 40 mg/kg cocaine dosed animals in comparison to the saline injected controls ( $p < 0.05$ ).

STRUCTURE-AFFINITY RELATIONSHIPS ASSOCIATED WITH THE STANDARD 5-HT2 SEROTONIN LIGAND KETANSERIN. A. M. Ismaiel,\* M. Teitler,\* and R. A. Glennon, Department of Medicinal Chemistry, MCV/VCU, Richmond, VA 23298-0540. The most widely used 5-HT2 serotonin receptor antagonist is ketanserin. And yet, essentially nothing is known about how its structural features influence affinity. Furthermore, ketanserin binds with high affinity at 5-HT1C receptors. The 5-HT2 affinities of a series of ketanserin analogs were systematically investigated to determine which features contribute to binding and selectivity. (i) Removal of the F atom and elimination of the carbonyl oxygen of the benzoyl group have little effect on affinity, whereas reduction of the carbonyl group decreases affinity by  $> 100$ -fold. (ii) An intact piperidine ring is required for high affinity. (iii) The quinazoline portion of the molecule is unnecessary, per se, for binding and can be replaced with structurally simpler moieties. Several of these latter derivatives also display greater 5-HT2 vs. 5-HT1C selectivity than ketanserin itself.

The use of an empirical hydrophobic field in the modeling of cyclodextrin drug inclusion complexes. H.L.Jiang, G.E.Kellogg and S.F.Semus, Division of Biomedical Engineering, Medical College of Virginia, Virginia Commonwealth University, Richmond, Virginia 23298-0694.

Cyclodextrin analogues (CDA) have been well known for their ability to form inclusion complexes with a great variety of drug molecules. The hydrophobic moieties of drug molecules bind non-covalently in the internal cavities of CDA. The binding interactions are characterized primarily as short range hydrophobic interactions between drug and carrier. These interactions have been examined using atomic constants derived from the fragment method of Hansch and Leo. The results of these calculations were investigated visually by importing field maps into commercial molecular modelling software. This technique has enabled us to study crystallographically derived drug inclusion complexes and understand the nature of such interactions as well as determine the strength of binding between the molecules.

ACUTE AND CHRONIC COCAINE ADMINISTRATION DISRUPTS THE INITIATION AND MAINTENANCE OF MATERNAL BEHAVIOR IN LACTATING RATS. C.H. Kinsley, A. Bauer\*, M. Beverly\*, D. Turco\* & J. Wellman<sup>†</sup>, Dept. Psychology, Univ. of Richmond, Va, 23173. Though much attention has been devoted to the behavioral and physiological consequences of cocaine (COC) abuse, little is known regarding the effects on maternal behavior (MB). We examined whether COC affects the initiation and/or maintenance of MB. In Exp. 1 COC (5-10 mg/kg) or saline was administered on PP day 5 or 6 and MB scored. 5 mg/kg was marginally effective ( $p < 0.1$ ), whereas 10 mg/kg significantly disrupted full MB. Exp. 2 (with 10 mg/kg) examined specific elements of the disruption and found increases in the latencies to contact, retrieve, lick, group and crouch over pups. In Exp. 3 osmotic mini-pumps containing 20 mg COC/kg/day or saline were implanted sc in day 14 pregnant rats. MB testing was performed on days 1-2 PP together with a T-maze pup-retrieval test on PP days 3-5. COC disrupted MB and performance in the T-maze tests, in general, rendering the females less attentive to young.

THE INFLUENCE OF PRENATAL STRESS IN THE ACTIVITY-STRESS PARADIGM. K.G. Lambert, Dept. of Psyc., Randolph-Macon Col., Ashland, Va. 23005, C.H. Kinsley, Dept. of Psyc., Univ. of Richmond, Richmond, Va. 23173, H.J. Jones, S.L. Klein, S.N. Peretti, & K.M. Stewart, Dept. of Psyc., Randolph-Macon Col.

The role of prenatal stress (PS) on subsequent exposure of the offspring to the activity-stress (A-S) paradigm was investigated. Fifty-six female primiparous Sprague-Dawley rats were time-mated and then assigned to either a PS or control group. PS females were exposed to heat and restraint-stress thrice daily on post-conception days 14-21. At parturition, all pups were cross-fostered. Following weaning, one or two female (n=16) or male (n=16) pups were selected from each litter. The A-S paradigm began when rats were approximately 58 days of age. Following 4 days of habituation to the wheel, all rats received restricted feeding for 14 days. Animals were sacrificed as they appeared moribund. Results revealed that PS rats ran less than controls during the habituation period to the wheel; whereas, a sex effect was found for experimental activity (females ran more than males). Additionally, in a nonsignificant trend, PS rats developed less ulceration in response to A-S. Finally, females had a heavier relative adrenal weight than controls. The role of the pituitary-adrenal cortex in the PS rats' response to subsequent stress is discussed.

CENTRAL MECHANISMS OF CANNABINOID-INDUCED ANTINOCICEPTION  
Aron H. Lichtman, Stacie Cook, and Billy R. Martin Department of Pharmacology and Toxicology, Medical College of Virginia-Virginia Commonwealth University

Rats were injected with the cannabinoid analog, CP-55,940, through chronic brain cannulae aimed at various regions of the periaqueductal gray (PAG) and assessed for both nociception in the tail-flick test and catalepsy in a 5 min ring immobility test. Microinjection of CP-55,940 (15 µg) into the posterior ventrolateral region of the PAG produced potent antinociception ( $84 \pm 16\% MPE$ ) and catalepsy ( $152 \pm 26$  sec). These effects were regionally specific as drug administration to either the posterior dorsolateral or anterior ventrolateral PAG had little or no impact. A 4 day pretreatment with pertussis toxin (0.2 µg) completely blocked the antinociceptive and cataleptic effects of CP-55,940 administered into the posterior, ventrolateral region of the PAG. These findings indicate that the cannabinoids produce antinociception in a regionally specific manner in the PAG through an inhibitory action at a G-protein coupled receptor mechanism.

**COCAINE INDUCES POST-TRAUMATIC HYPOTENSION FOLLOWING EXPERIMENTAL BRAIN INJURY IN RATS: PROPOSED ADRENERGIC-OPIATE INTERACTION** J.K. Muir and E.F. Ellis\*, Department of Pharmacology and Toxicology, Medical College of Virginia, Richmond, VA 23298

The pharmacological activities of cocaine include sympathomimetic and local anesthetic actions. The sympathomimetic properties are due to its ability to block synaptic reuptake of norepinephrine (NE). The purpose of this study was to see if cocaine would alter blood pressure (BP) following fluid percussion injury, since this model of brain injury involves the massive release of catecholamines from the adrenal cortex. Sprague-Dawley rats ( $n=32$ ) were anesthetized with barbiturates. The animals were ventilated with room air and blood gases were maintained within normal limits. The animals were prepared for brain injury as previously described (Muir & Ellis, FASEB J 6:A1168, 1992).

Cocaine (2 mg/kg, iv) or saline was administered over a sixty second period and ten minutes later the animals received a moderate level of injury (2.0-2.1 atm). Upon injury both groups showed a similar initial hypertensive phase, but this phase was followed by a period of pronounced hypotension in the cocaine group. BP recovers and is similar to the saline controls by 20 minutes post injury. Pretreatment with methamphetamine (1 mg/kg, iv), but not lidocaine (2 mg/kg, iv), produces post-traumatic hypotension. The data suggest that post-traumatic hypotension was due to cocaine's sympathomimetic actions.

We propose that cocaine alters central cardiovascular regulation by enhancing the activation of alpha<sub>2</sub> receptors by NE in the brainstem. This can result in reduction in BP by reducing central sympathetic outflow or by the release of endogenous opiates, which have been shown to increase parasympathetic activity. Future studies will attempt to pharmacologically block cocaine-induced post-traumatic hypotension with receptor antagonists for adrenergic, opiate and cholinergic sites.

**A SYSTEMS APPROACH TO MODELING AND SIMULATING THE INTERACTIONS BETWEEN CELLS IN A SOLID TUMOR.** J.A. Pridgeaux. Biomedical Engineering Program, MCV, VCU, Richmond, VA. Tumors are composed of heterogeneous cell populations which reciprocally influence each other's growth. A computer program was designed to simulate the interactions among tumor cells. Hypothetical cell growth stimulatory and inhibitory factors, as well as their respective receptors, were included in the model microenvironment. The model permitted assessment of the following events across time: cell division, cell death, receptor site regulation, and secretion of growth regulatory factors at a rate which was a function of the concentration of the factors and their respective receptors. The effect of deleting different subpopulations was studied across time. The following results were observed: (1) The population sought a heterogeneous arrangement of phenotypes, (2) If a subpopulation was deleted, the overall population quickly evolved into a new heterogeneous configuration. (3) For different simulations, the observed population behavior ranged from (a) a static number of cells to (b) growth followed by rapid extinction to (c) unchecked growth for the duration of the simulation. (4) The impact of clonal deletion was different for different phenotypic traits. Thus the simulated program approach may provide a useful model of tumor dynamic behavior which duplicates some known biological phenomena.

**EFFECTS OF THE INTERACTIONS OF MORPHINE AND CANNABINOIDS ON SECOND MESSENGER SYSTEMS IN THE PRODUCTION OF ANTINOCICEPTION IN THE SPINAL CORD.** George Pugh, Jr. and Sandra P. Welch, Dept. of Pharmacology and Toxicology, Medical College of VA, Richmond, VA 23298

Intrathecal administration (i.t.) of  $\Delta^9$ -THC synergizes with morphine resulting in a parallel 10-fold shift in the morphine dose-response curve which is blocked by naloxone. This finding indicates  $\Delta^9$ -THC enhances the effects of morphine by interacting at opiate sensitive sites. The mechanism for this synergistic interaction is unknown, but may involve modulation of cAMP,  $[Ca^{++}]_i$ , or K<sup>+</sup> channel activity.

In mouse brain synaptosomes,  $\Delta^9$ -THC and morphine were additive in inhibiting adenylate cyclase activation.  $\Delta^9$ -THC (1 $\mu$ M) alone produced a 10% decrease over forskolin (10 $\mu$ M) stimulated adenylate cyclase (from 159 pmol/mg/min to 142.8 pmol/mg/min). Morphine (1 $\mu$ M) produced a 13% decrease over forskolin-stimulated adenylate cyclase (from 159 pmol/mg/min to 138 pmol/mg/min). In combination, both drugs produced a 27% decrease. In addition  $\Delta^9$ -THC and morphine interact in the modulation of cAMP levels in the spinal cord. Both  $\Delta^9$ -THC (10 $\mu$ M) and morphine (10 $\mu$ M) attenuate KCl induced rises in  $[Ca^{++}]_i$  in the brain using fura-2 as a calcium indicator. The dose response curve for  $\Delta^9$ -THC is shifted to the left in a non-parallel manner by i.t. Ca<sup>++</sup>. Antinociception produced by  $\Delta^9$ -THC is attenuated by verapamil i.t. The interaction of  $\Delta^9$ -THC,  $\Delta^8$ -THC, CP-55,940 and morphine with K<sup>+</sup> channels was examined. Morphine i.t. was blocked by glyburide (150 $\mu$ g/mouse i.t.), a blocker of ATP-gated K<sup>+</sup> channels, but not by apamin or charybdotoxin, blockers of Ca<sup>++</sup> gated K<sup>+</sup> channels. Conversely, the cannabinoids were potently blocked by apamin (10ng/mouse i.t.) but not by glyburide or charybdotoxin. These data indicate that the modulation of cAMP,  $[Ca^{++}]_i$ , and K<sup>+</sup> channel activity by the opiates and cannabinoids are possible mechanisms by which these drugs synergize. This work was supported by grants DA 05274 and DA 06031.

CALCIUM CHANNEL INACTIVATION: A NEW MECHANISM TO EXPLAIN ISLET CELL ELECTRICAL ACTIVITY? Leslie S. Satin and Steven J. Tavalin, Dept. of Pharm./Tox., Med. Coll. of Va., Va. Commonwealth Univ., Richmond, VA. 23298. Electrical activation of pancreatic islet  $\beta$ -cells by plasma glucose is needed for insulin secretion but is not understood. Sugar metabolism causes bursts of calcium (Ca)-dependent voltage spikes triggered by slow plateaus, which mediate Ca uptake and secretion. Bursting was thought to be due to potassium current activation by entering spike Ca. New data suggests this is not the case. To study an alternative model based on Ca current, cultured insulin-secreting HIT cells were patch clamped. Ca current activated within 5 msec and inactivated with a biphasic time course following a 10s command. The slow phase was voltage-dependent and its kinetics resembled the slow plateaus. Models based on the results showed that inactivation was a feasible bursting mechanism. To test for Ca current inactivation during bursting, a burst-like voltage command was applied to single cells. As predicted by our model, Ca current slowly inactivated during the artificial burst. These data suggest that slowly inactivating Ca current may control bursting. This approach will now be used to test other other ionic hypotheses of bursting. We thank P. Smolen of the NIDDK for his help. Supported by an A.D.Williams Award.

AFFINITY OF N-ALKYL AND N-ALKENYL-NORMETAZOCINES FOR MU OPIOID AND PHENCYCLIDINE RECEPTORS. C. SAUSS, N.I. UWAYDAH, E.L. MAY, R.L. BALSTER, L.S. HARRIS, B.R. MARTIN. Dept. Pharm/Tox, MCV/VCU, Richmond, VA.

Early studies of the benzomorphan group utilizing the N-allyl-analog of normetazocine (NANM, SKF 10,047) have shown that the (+) isomers of NANM and related benzomorphans are relatively specific PCP-like drugs, whereas the (-)-isomers have typical mu and/or kappa opioid actions. Variation of substituents on the benzomorphan nucleus, particulary on nitrogen, results in significant changes in biological responses. The present study shows that the binding potency and selectivity of alkyl- and alkenyl- normetazocine (NM) analogs to the PCP and mu opioid receptor sites are sensitive to changes in the N-substituent and to the stereochemistry of the benzomorphan. (+) N-Normetazocine displays the highest affinity for the PCP receptor followed by (+) metazocine, which is only slightly less potent. None of the other analogs, all of which possess larger N- substituents, showed appreciable affinity for the PCP site. The (-)-isomers of alkyl- and alkenyl- NM analogs were much more potent than the (+)-isomers for the mu opioid site. Additionally a good correlation exists between in vitro affinity for the opioid receptor and in vivo activity in antinociceptive assays. In this study we determined the affinities of alkyl- and alkenyl-NM analogs for the PCP and mu opioid receptor to define the structural requirements for benzomorphans having activity at these receptors. [Supported by NIDA grants DA-05721, DA-02396 and DA-00490.]

THE EFFECT OF CALCITONIN GENE-RELATED PEPTIDE ON THE LOCAL ANESTHETIC EFFICACY OF MEPIVACAINE. Mark A. Saxen, William L. Dewey, and Robert L. Campbell, Department of Pharmacology and Toxicology and Department of Oral and Maxillofacial Surgery, Medical College of Virginia, Virginia Commonwealth University, Richmond, VA 23298-0613. Calcitonin gene-related peptide (CGRP) attenuates the local anesthetic effect of mepivacaine. We sought to determine if this effect was due to a direct sensitization of primary afferent neurons via sensory-efferent actions, or rather the result of vasodilation produced by CGRP. We measured CGRP levels and heat nociceptive threshold in the dorsal hindpaw skin after inducing inflammation and injecting CGRP; neither showed evidence of direct sensitization. Experiments with capsaicin and the CGRP antagonist, CGRP (8-37) showed the actions of CGRP to be totally consistent with the actions of other vasodilators. We conclude that the effect of CGRP on the action of mepivacaine is due to vasodilation. Supported by NIDR grant DE00151, NIDA grant DA06031 and DA01647.

THE EFFECTS OF INFLAMMATION ON FETAL WOUND HEALING. Matthew C. Schaefer, Jack L. Haar\*, Dept. of Anat., Frazier W. Frantz\*, Robert F. Diegelmann\*, Dept. of Surg., Div. of Plast. and Reconstr. Surg., Med. Col. of Va., Va. Comm. Univ., Richmond, VA, 23298. Recent experimental data support the clinical observation that the fetus and neonate respond to injury in a very different and distinct fashion as compared to the adult. Linear wounds in the mammalian fetus heal rapidly with minimal or no scar formation. On a cellular level, fetal wounds lack an acute inflammatory response and do not exhibit a prominent proliferative fibroblast response. In adult repair, the collagenous extracellular matrix (ECM) is deposited in a highly disorganized fashion resulting in an unsightly and structurally inferior scar. Adult wound healing is an imperfect process, in that wound dehiscence, fibrosis, and contractures are common clinical complications. In contrast, the ECM of the fetal wound consists predominantly of the glycosaminoglycan hyaluronic acid (HA). The small amount of collagen in the fetal wound is deposited in an orderly fashion similar to normal, undamaged, skin. Ultimately, fetal healing results in restoration of both normal dermal architecture and breaking strength. Therefore, fetal wound healing more resembles regeneration than repair.

Preliminary data reveal ultrastructural and morphological differences between fetal and adult inflammatory cells and wound tissue. The fetus can also mount an adult-like inflammatory response when sufficiently stimulated. Also, with prolonged inflammation at the wound site, fibrosis and scar formation can be induced in the fetus. Understanding the control mechanisms that endow the fetus with unique, "scarless", healing capabilities has tremendous potential benefit in future manipulation, regulation, and treatment of many human adult wound healing problems.

EFFECTS OF PYRIMIDO TRIAZINOINDOLE (BUT/PTI) COMPOUND ON TRYPANOSOMA MUSCULI INFECTION IN FN MALE MICE. Dilip K. Sen, Godwin O. Mbagwu, David Mason, and William Jones. Depts of Life Sci. and Dept. of Chem., Va State Univ., Petersburg, Va. 23806. A Pyrimidio Triazinoindole BUT/PTI was tested to measure host-resistance to stercorarian hemoflagellate by studying T. musculi cell population in vivo. The injection of the test compound in the infected animals affected the level of parasitemia in FN mice. During most of the observation period, the mice receiving BUT/PTI after inoculation of trypanosome, simultaneously with inoculation of parasites or prior to the inoculation of parasitic protozoan developed lower parasitemic levels when compared with the untreated but infected controls. The timing of administration of the test drug appeared to have been an important parameter of the observed effects. (Supported by the NIH Grant MPRC-B 5 S14 GM44814-02).

IN VITRO AND IN VIVO EVALUATION OF 6-HYDROXYDOPAMINE AND 5-HYDROXYDOPAMINE ON THE PRIMARY ANTIBODY RESPONSE IN B6C3F1 MICE. Tracey L. Spriggs and Bruce A. Fuchs\*, Dept. of Pharmacology and Toxicology, Medical College of Virginia, Richmond, Va. 23298. The neurotoxin 6-hydroxydopamine (6-OHDA) has been used to explore the possible relationship existing between the humoral immune response and the sympathetic nervous system. The present study investigates *in vitro* and *in vivo* generated primary antibody forming cell (AFC) responses to sheep red blood cells (sRBC) of mice treated with 6-OHDA or its non-neurotoxic isomer, 5-OHDA. For the *in vitro* studies, mice were administered 200 mg/kg of compound intraperitoneally (i.p.) on day five and day two prior to sacrifice. Spleens were placed into Mishell-Dutton cultures and the AFC response determined. 6-OHDA significantly suppressed the *in vitro* AFC response while 5-OHDA did not. The 6-OHDA-induced decrease in the *in vitro* AFC response was blocked by pretreatment with the adrenergic uptake inhibitor desipramine. Furthermore, 6-OHDA, but not 5-OHDA, induced a significant decrease in thymus weight and cellularity which were also blocked with desipramine. The *in vivo* AFC response was determined in mice that received 200 mg/kg i.p. of compound three days and thirty minutes prior to immunization. Four days post immunization, mice were sacrificed and the *in vivo* AFC response assessed. The 6-OHDA treated mice demonstrated a significant suppression of the AFC response; however, 5-OHDA treated mice also displayed a decreased AFC response. Desipramine pretreatment blocked both the 6-OHDA and the 5-OHDA-induced decreases in the *in vivo* generated AFC response. These data suggest that while the decrease in the *in vitro* AFC response may be the result of adrenergic neuronal destruction, the suppression of the *in vivo* AFC response appears to be mediated by other factors. (Supported by NIMH grant R29 MH 45931-02 and ES55094.)

ROLE OF NITRIC OXIDE IN N-METHYL-D-ASPARTATE-STIMULATED NEUROTRANSMITTER RELEASE. Amy K. Stout and John J. Woodward, Dept. of Pharmacology and Toxicology, Med. Col. of Va., Va. Commonwealth Univ., Richmond, VA 23298. Activation of the N-methyl-D-aspartate (NMDA) subtype of glutamate receptor has been reported to stimulate the synthesis of nitric oxide (NO) via calcium influx and activation of NO synthase. Since previous experiments in our lab have shown that NMDA dose-dependently stimulates the release of tritiated norepinephrine from preloaded hippocampal slices of adult male Sprague-Dawley rats, this system was used to investigate the role of NO in NMDA-stimulated processes. Sodium nitroprusside, which generates NO upon reacting with reduced sulphydryl groups, inhibited transmitter release at concentrations which also stimulated increases in cyclic guanosine monophosphate (cGMP) levels in cultured neurons. The inhibitory effect of nitroprusside was not due to the formation of cyanide ions, a breakdown product of nitroprusside, since potassium cyanide enhanced rather than inhibited NMDA-stimulated release. Pretreatment of the slices with the sulphydryl reducing agent dithiothreitol more than doubled NMDA-stimulated release and decreased the inhibitory potency of nitroprusside. Pretreatment of the slices with the sulphydryl oxidizing reagent 5,5'-dithio-bis(2-nitrobenzoic acid) had no effect on NMDA-stimulated release by itself but blocked the inhibitory effects of nitroprusside. Hemoglobin, an iron-containing protein which binds NO, also blocked the ability of nitroprusside to inhibit release. These results suggest that NO synthesized upon NMDA receptor activation could feedback to inhibit subsequent NMDA-mediated processes.

STRUCTURE-ACTIVITY RELATIONSHIP OF N-SUBSTITUTED N-NORMETAZOCINE ANALOGS FOR BINDING TO PCP AND  $\mu$  OPIOID RECEPTORS. N. I. Uwaydah, C. Sauss, E.L. May, L.S. Harris and B.R. Martin. Dept. of Pharm/Tox, MCV/VCU, Richmond, VA 23298.

The optical antipodes of N-allyl-N-normetazocine share some of the behavioral properties of PCP which led to their use in distinguishing PCP and  $\mu$  opioid receptors. To gain further insight into the structural requirements of the benzomorphans to bind to these two receptors, optical antipodes of NSNM analogs were synthesized and evaluated for their ability to compete for  $^3$ H-TCP (KD = 7.7 nM) and  $^3$ H-DAMGO (KD = 1.9 nM) binding to rat brain membranes as well as for their in vivo properties. All of the analogs exhibited a large degree of stereoselectivity for the  $^3$ H-DAMGO site with the greatest affinity residing in the (-)-isomers. The allyl-derivatives, N-allyl-normetazocine and N-chloroallyl-normetazocine, which were very potent analogs in the opioid assay, exhibited strong narcotic antagonist activity as shown in the TF v M test, which corresponded with the affinity for the receptor. A good correlation seems to exist between *in vitro* affinity towards the opiate receptor and *in vivo* activity in antinociceptive assays. In contrast, the analogs demonstrated only modest stereoselectivity for the  $^3$ H-TCP site. (-)- $\beta$ -Cyclazocine and (-)- $\alpha$ -Cyclazocine showed the highest affinity for the PCP receptor and also displayed PCP-like effects as shown in the PCP drug-discrimination paradigm. None of the other analogs showed an appreciable affinity for the PCP site nor PCP-like properties. More behavioral evaluations of the analogs are necessary for correlations to be made with TCP and DAMGO binding. Supported by NIDA grants DA-05721, DA-02396 and DA-00490.

TUMOR-INDUCED ALTERATIONS OF CYTOKINE SYNTHESIS. Thomas M. Walker and Klaus D. Eigert. Dept. of Biology, Microbiology and Immunology Section, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061-0406.

Tumor growth suppresses immune responsiveness through changes in macrophage (M $\phi$ ) phenotype and function. Phenotypic changes include decreased expression of major histocompatibility complex (MHC) class II molecules, and functional changes include alterations in accessory ability and cytokine synthesis. Granulocyte-macrophage colony-stimulating factor (GM-CSF) is an important regulatory cytokine produced by M $\phi$  during activation and antigenic challenge. Because the amount of GM-CSF produced during antigenic challenge partially dictates the level of immune responsiveness, we wanted to determine if tumor growth compromises immune responsiveness through changes in GM-CSF production. Using the GM-CSF-dependent cell line DA3, we determined tumor growth significantly alters M $\phi$  production of GM-CSF. Both splenic and peritoneal tumor-bearing host (TBH) M $\phi$  produce less GM-CSF than normal host (NH) M $\phi$ . In response to lipopolysaccharide (LPS), splenic MHC class II $^+$  TBH M $\phi$  also produce less GM-CSF than their NH counterparts, but only when stimulated with low doses of LPS. When cultured with GM-CSF, TBH M $\phi$  fail to express higher levels of MHC class II molecules and MHC class II $^-$  TBH M $\phi$  become more suppressive than their NH counterparts during recognition of foreign cell surface antigens. These results collectively suggest that M $\phi$  production of GM-CSF is disrupted during tumor growth and that these changes contribute to reduced immunocompetence. This work was supported in part by the Horsley Cancer Research Fund, a Sigma XI grant, and a VPI & SU Graduate Research and Development Program grant.

SPATIAL ORGANIZATION AND NEUROTRANSMITTER UTILIZATION OF PREMOTOR NEURONES RELATED TO VERTICAL SACCADIC EYE MOVEMENTS IN THE CAT. Shwu-Fen Wang and Robert F. Spencer\*, Department of Anatomy, Medical College of Virginia, Richmond VA 23298

Morphological, physiological, and clinicopathologic studies have established that the rostral interstitial nucleus of the medial longitudinal fasciculus (riMLF) is the location of premotor neurones that control vertical saccadic eye movements. Toward the goal of delineating an intrinsic organization of neurones in the riMLF in relation to upward and downward eye movements, microinjections of the retrograde tracer, horseradish peroxidase (HRP), and the anterograde tracer, biocytin, have been made in different regions of the oculomotor nucleus and the riMLF, respectively. The results demonstrate a caudal-upward and rostral-downward relation of the neurones in the riMLF to their targeting vertical motoneurones in the ipsilateral oculomotor and trochlear nuclei. Two populations of synaptic endings from the riMLF are labelled: presumed inhibitory synaptic endings that contain pleiomorphic synaptic vesicles and establish symmetrical synaptic contacts, and presumed excitatory synaptic endings that contain spheroidal synaptic vesicles and establish asymmetric synaptic contacts. Both populations of synaptic endings overlap in the same motoneurone subgroups and target predominantly medium- and small-diameter dendrites. The presumed inhibitory synaptic endings are GABA-immunoreactive, while the presumed excitatory synaptic endings are immunoreactive toward glutamate. This ipsilateral inhibitory and excitatory organization of riMLF projections to vertical motoneurones differs from the characteristic reciprocal ipsilateral inhibitory and contralateral excitatory synaptic connections in the vertical vestibulo-ocular and horizontal eye movement systems. (Supported by USPHS MERIT Award EY02191 from the National Eye Institute.)

DISRUPTION BY MORPHINE, AND RESTORATION BY NALOXONE, OF THE PARENTAL-LIKE BEHAVIOR DISPLAYED BY JUVENILE RATS. J. Wellman\*, D. Carr\*, A. Graham\*, J. Jones & C.H. Kinsley, Dept. Psychol., Univ. of Richmond, Va. 23173. Juvenile rats (20-30 days of age) respond to foster pups with full parental behavior (FPB: retrieving, grouping and crouching). Since FPB can be disrupted by morphine (MOR) in adult females (which effect is antagonized by naloxone [NAL]), we examined the latters' role in affecting FPB in juveniles. In Exp. 1, 25 day-old juveniles were given 1 of 3 treatments of MOR, saline (SAL) or NAL (MOR+SAL; MOR+NAL; or SAL+SAL) and exposed to pups. Whereas the SAL+SAL and MOR+NAL were not different, MOR+SAL virtually failed to show FPB over a ten day period. In Exp. 2, FPB-responding juveniles were treated with the same regimen as above. SAL+SAL and MOR+NAL responded rapidly to young, whereas MOR+SAL did not. These data suggest that the display of parental-like behavior, both its onset (Exp. 1) and its maintenance (Exp. 2), appears to be regulated by opiates. Juveniles, therefore, may represent an interesting model in which to investigate developmental influences on parental behavior.

PROTEOGLYCANS OF HUMAN OCULAR TISSUE. Marcus Wynn and Dr. H. Alan Rowe, Department of Chemistry, Norfolk State University, Norfolk, VA 23504

Proteoglycans (PG) are a class of molecules that form the ground substance in the extracellular matrix of connective tissue. Corneal tissue can be used as "non-target" tissue to study the involvement of PG in arteriosclerosis. Non-transplantable corneas are separated into two experimental groups, A & B. Group A contains tissue from donors with a medical history of cardiovascular disease and group B contains control tissue. Corneas in groups A & B are weighed, minced, and extracted twice at 4 °C with 4.0 M guanidine HCl in 0.05 M sodium acetate, pH 4.5 in the presence of protease inhibitors. The extracted samples from both groups were dialyzed versus 0.05 M sodium acetate to evaluate the aggregable and non-aggregable PG. Proteoglycans were separated using gel filtration chromatography on Sepharose CL-4B with the peak fractions pooled and further purified using CsCl buoyant density ultracentrifugation. Hexuronic acid and protein assays were conducted at each purification step to assess the fold-purification during each procedure via the specific activity. The concentration of PG is greater in the A group and structural differences in the isolated macromolecules are noted. Supported by NIH-MARC and the Norfolk LIONS Medical Eye Bank and Research Center.

EFFECTS OF FIBROBLAST GROWTH FACTOR ON ACCESSORY SEX GLANDS OF PREPUBERTAL MICE. Robert E. Yoder, John L. Rittenhouse, Judith L. Leatherman, and Roman J. Miller, Dept. of Biology, Eastern Mennonite College, Harrisonburg, Va. 22801. In order to investigate the possible stimulatory role of fibroblast growth factor (FGF) on prepupal accessory sex gland growth and function, 20 day old Swiss-Webster mice were placed in groups and treated with five injections within a period of 10 days consisting of: (I) Control, BSA&Oil; (II) FGF, 125 ng; (III) DHT, 2 mg; and (IV) FGF&DHT, 125 ng & 2 mg. At 30 days of age, accessory sex glands were removed, weighed and frozen in liquid nitrogen for later analysis. Using polyacrylamide gel electrophoresis, one dimensional soluble protein profiles, based on molecular weight, were obtained for seminal vesicle (SV) and anterior prostates (AP) glands. SV & AP wet weights showed significant DHT enhancement with increases of 200% and 165%, respectively, above controls. FGF alone had no significant enhancement, but in combination with DHT showed a drop of 9% in AP as compared with the DHT group. Gel protein profiles of SV showed a 89.4 k-dalton protein enhanced by DHT, but inhibited by FGF&DHT group. AP protein profiles showed a 45 k-dalton protein greatly enhanced by FGF alone.  
(Research supported by D.B. Suter Program Endowment of EMC.)

## Microbiology and Molecular Biology

RPOA MUTANTS AFFECTING P2 LATE GENE EXPRESSION. Deborah J. Ayers and Gail E. Christie, Dept. of Microbiology and Immunology, VCU, Richmond, VA 23298. Late gene transcription in temperate coliphage P2 requires the host RNA polymerase and Ogr, a P2-encoded transcriptional activator. P2 late genes can also be transactivated by the product of the  $\delta$  gene of satellite phage P4. P2 late transcription is blocked by a point mutation, *rpoA109*, in the  $\alpha$  subunit of *E. coli* RNA polymerase. Compensatory mutations in *ogr* and  $\delta$  have been isolated, which suggests that the  $\alpha$  subunit of RNA polymerase interacts with these phage-encoded activators. We have obtained existing *rpoA* mutants of *E. coli* and *S. typhimurium* which were selected on the basis of impaired expression of other positively regulated promoters. The effects of these mutations on the expression of the *cat* gene fused to a P2 late promoter were assayed in the presence of either Ogr or  $\delta$ . Our results suggest that the area around amino acids 289 and 290 in the C-terminal domain of the  $\alpha$  subunit of RNA polymerase is important for the positive control of P2 late gene transcription. In order to elucidate the putative interaction between the  $\alpha$  subunit and the phage-encoded activators, we have developed a method for the selection of additional mutations in the *rpoA* gene which affect P2 late transcription. This selection should yield mutants which are blocked in the transactivation, by P4  $\delta$ , of the lysis function encoded on a P2 prophage.

ATTEMPTS TO PREDICT FOLDING PATTERNS OF VIRUS CAPSID PROTEINS. Sandra Boatman and Mary Englund, Dept. of Chemistry, Hollins Col., Roanoke, VA 24020. To understand the stabilizing interactions, assembly, and uncoating of small, isometric viruses, it would be extremely useful to know the tertiary structure of protein subunits making up the virus capsids. From crystallography, the folding patterns of a few such viruses are known. Predictions of regions of secondary structure using models currently available do not correlate with these known structures; therefore, the models probably do not predict well the folding patterns of capsid proteins of unknown tertiary structures. This paper presents results of preliminary attempts to develop a model that will more successfully predict the folding patterns of virus capsid proteins.

MAIZE UBIQUITIN (UBI-1) GENE PROMOTER ANALYSIS. Donna M. Fox and Alan H. Christensen, Department of Biology, George Mason University, Fairfax, VA 22030. Ubiquitin is a highly conserved 76 amino acid protein found in all eukaryotes and it participates in a variety of vital cellular processes. When fused to the reporter gene chloramphenicol acetyl transferase (CAT), 0.9 kbp of the maize ubiquitin (Ubi-1) gene promoter directs a high level of CAT expression in electroporated maize protoplasts. The cis-regulatory sequences in this region that are required for this high level of expression are being identified. A set of deletions beginning at the 5' end of the ubiquitin promoter sequence and spanning the entire region has been constructed and fused to the CAT reporter gene. The chimeric genes have been electroporated into maize protoplasts and the promoter function analyzed. Results indicate that sequences between -899 and -555 contribute little to expression from the Ubi-1 promoter. Most of the promoter activity can be attributed to the 100 base region upstream of the transcription start site. (Supported by the Thomas F. Jeffress and Kate Miller Jeffress Memorial Trust)

THE ENHANCEMENT OF OXYGEN TOLERANCE IN *CAMPYLOBACTER* AND RELATED MICROAEROPHILES BY AGENTS THAT QUENCH ACTIVE OXYGEN. Jeffrey P. Hodge and Noel R. Krieg, Dept. of Biol., Va. Polytechnic Inst. and State Univ., Blacksburg, VA 24061. Previous work in our laboratory showed that oxygen tolerance in the microaerophile *Campylobacter jejuni* strain H840 can be enhanced by various chemical agents that quench active forms of oxygen. Brucella medium prepared with Gibco peptones had been used in those experiments. In the present study we attempted to test other potential agents in a similar manner; however, we used Brucella medium prepared with Difco peptones because the Gibco peptones are no longer manufactured. Although preliminary results suggest that allopurinol, azelaic acid, caffeine, DMSO, and pyruvate may facilitate growth of strain H840, we found that the brand of peptone in Brucella medium can greatly influence the results. For instance, unsupplemented Brucella medium prepared with Difco pancreatic digest of casein supported growth up to 15-21% O<sub>2</sub>, but when the medium was prepared with putatively similar Gibco or BBL pancreatic digests it allowed growth only up to 10% O<sub>2</sub>. The factors responsible for these differences in peptones is currently under investigation. (Supported by the Sigma Xi Grants-in-Aid Program)

ENHANCER-LIKE SEQUENCES INVOLVED IN REGULATION OF THE CITRATE SYNTHASE GENE CIT1 OF *Saccharomyces cerevisiae*. Christine S. Kell, Elizabeth A. Pennell\*, and Mark S. Rosenkrantz\*, Dept. of Microbiology and Immunology, Va. Commonwealth Univ., Richmond, Va 23298. In *S. cerevisiae*, the nuclear gene CIT1 encodes the major isozyme of citrate synthase, which catalyzes the first and rate-limiting step of the mitochondrial tricarboxylic acid (TCA) cycle. Transcription of CIT1 is reduced synergistically by glucose and glutamate in the growth medium (but not by glutamate alone), reflecting the roles of the TCA cycle in catabolism and biosynthesis. The TATA box and transcription initiation sites lie at -195 and -140 to -100, respectively (relative to the CIT1 coding sequence). By deletion analysis of a CIT1-lacZ gene fusion and by heterologous gene constructs, it was determined that DNA sequences located between -458 and -210 are necessary and sufficient (in either orientation) for activation and regulation of transcription by glucose and glutamate. Catabolite derepression of CIT1 is prevented in mutants which lack the nuclear Hap2,3,4 trimeric transcriptional activator protein. Hap2,3,4 also activates expression of other nuclear genes required for mitochondrial respiratory function. Mutation of candidate HAP2,3,4-binding sites (TNATTGGT) at -310 and -290 prevents derepression of CIT1. The Hap2,3,4-independent mechanisms for catabolite-repressed expression of CIT1 and for regulation by glutamate are also being explored by the isolation of mutants defective in expression of CIT1-lacZ and characterization of the DNA-binding activities in extracts from these mutant strains.

## COMPARISON OF CELL MEMBRANE PROTEINS OF AVIAN MYCOPLASMAS.

Jennifer A. McCusker and Lynn O. Lewis, Dept. of Biological Sciences, Mary Washington Col., Fredericksburg, VA 22401-5358.

Among the species of Mycoplasma described in Bergey's Manual, four are known to be pathogens for domestic poultry. These species are Mycoplasma gallisepticum, which produces chronic respiratory disease in chickens and turkeys, M. synoviae, which produces infectious synovitis in chickens and turkeys, M. meleagridis, which produces respiratory disease only in turkeys, and M. iowae, which produces death of turkey and chicken embryos. It is believed that the protein structure of the cell membrane determines pathogenicity by coding for attachment of the mycoplasma to avian tissues, thereby initiating infection and subsequent tissue damage. Through SDS-PAGE, the protein components of cell membranes from whole cell extracts of pathogenic and non-pathogenic avian mycoplasma species were examined and compared. This study emphasized three strains of M. gallisepticum: S6, which is virulent in chickens and turkeys; F10, which is virulent in chickens only; and A5969, which is nonvirulent in poultry.

CHARACTERIZATION OF A SIDEROPORE PRODUCED BY *SUILLUS VARIEGATUS* CULTURED UNDER IRON-LIMITING CONDITIONS. Judy H. Niehaus and April Falc, Dept of Biol. Radford Univ., Radford, Va. 24142. *Suillus variegatus*, a fungus mycorrhizal on *Pinus sylvestris*, produces a siderophore under iron-limiting conditions. Siderophores are extracellular, low molecular weight iron-chelating compounds that solubilize environmental iron for use by the fungus and possibly by the host. Pure cultures of *S. variegatus* were used to investigate the conditions necessary for siderophore production. Siderophore production can be measured by addition of ferric chloride to the colorless culture filtrate and spectrophotometric measurement of the resulting ferri-siderophore at 470 nm. In Grimm-Allen low iron medium siderophore production was found to be dependent on pH. Growth, measured by dry weight of mycelium, was best at pH 5.0 (6.4 g/l versus 2.3 g/l at pH 6.0 and 0.2 g/l at pH 4.0.). Total siderophore production was also higher at pH 5.0 ( $A_{470} = 0.711$ ) than at pH 4.0 ( $A_{470} = 0.007$ ) or pH 6.0 ( $A_{470} = 0.620$ ). Siderophores from *S. variegatus* were partially purified from a lyophilized pH 5.0 culture filtrate. Aliquots were adjusted to different pH's, lyophilized, and the dry powder extracted with ethanol. Two sequential extractions of the pH 5.0 sample resulted in 63% recovery of the original  $A_{470}$ . Only 19-31% recovery occurred with the pH 3, 4, 6, and 7 samples. Thin-layer chromatography of the siderophore in butanol:acetic acid:water (5:1:4) was visualized by spraying the chromatogram with ferric chloride. The unusual  $R_f$  of 0.82 suggests that this is a novel siderophore.

THE GLYCOPROTEINS OF *NAEGLERIA*. Anna L. Scott\*, Denise M. Toney, and Francine Marciano-Cabral, Dept. of Microbiology and Immunology, Medical College of Virginia, Richmond, Va 23298. *Naegleria fowleri*, a free-living amoeba with pathogenic potential, is the aetiologic agent of Primary Amoebic Meningoencephalitis. We have determined that *Naegleria* glycoproteins are important because they have been shown to play a role in resistance of highly pathogenic amoebae to complement-mediated lysis. The purpose of this study was to identify and compare the glycoproteins of highly pathogenic and weakly pathogenic *N.fowleri*. In order to investigate the glycoproteins of *Naegleria* we have used a lectin staining procedure. *Naegleria* membrane proteins were subjected to SDS-polyacrylamide gel electrophoresis, blotted to nitrocellulose and reacted with biotinylated lectins. The glycoprotein bands were visualized by staining reagents. Differences in the glycoproteins of highly pathogenic and weakly pathogenic strains of *Naegleria* were detected using the lectins Concanavalin A (specific for mannose), Soybean agglutinin (specific for galactosamine) and Wheatgerm agglutinin (specific for glucosamine). Glycoproteins which were present in the highly pathogenic amoebae, or present in greater quantities, were seen at 118, 81, 62, 42 and 33kD with Con A, at 69kD with Soybean and at 69 and 62kD with Wheatgerm.

**IDENTIFICATION OF DAMAGE-INDUCIBLE GENES IN SACCHAROMYCES CEREVISIAE.**

William Shanabruich and Susan B. McLeskey\*, Dept. of Biology, Univ. of Richmond, VA 23173. Transposon mutagenesis technology was developed to generate random lacZ fusions in the S. cerevisiae genome. The ability to create insertion mutations at a variety of loci was verified by physically mapping the positions of 22 randomly selected transposon insertions to a minimum of 8 different chromosomes and by detecting auxotrophs at a frequency greater than 0.1%. Over 20,000 insertion mutants were screened for induction of beta-galactosidase activity in response to methyl methanesulfonate, hydroxyurea, and/or ethyl methanesulfonate. Five DIN-lacZ fusion strains were identified which express 3-8 times more beta-galactosidase activity following induction with a DNA damaging agent. The characteristics of beta-galactosidase expression (dosage of inducer, spectrum of inducers, and kinetics of induction) for each strain are currently being examined as well as repair and mutagenesis phenotypes.

**DNA BASE COMPOSITION OF EUBACTERIA ISOLATED FROM FOUR SPECIES OF AZOLLA.** Brian Shannon, James Gates and Sara McCowen. Dept. of Biology, Virginia Commonwealth Univ., Richmond, Virginia 23284. Eubacteria, similar to previously described *Azolla*-associated *Arthrobacter*, were isolated from four species of *Azolla*: *A. caroliniana*, *A. mexicana*, *A. filiculoides*, and *A. microphylla*. The DNA base composition (GC content) of 20 eubacterial isolates, five from each fern species, ranged from 57.7 to 68.2%. 19 of the 20 isolates had a GC content greater than 59% and were therefore within the reported range for *Arthrobacter* species. Although all isolates were phenotypically similar, statistical analysis ( $p = 0.1$ ) indicated that each fern species contained at least two groups based on GC content. 17 isolates composed three overlapping groups with GC content of 59.1 to 65.2% which is in the reported range for *A. globiformis*. Our data are consistent with earlier reports that these *Azolla* isolates are arthrobacters, but suggest that different biotypes may exist within a leaf cavity of a single *Azolla* species.

## Psychology

**SELF-SELECTED CLASSROOM SEATING POSITION AND TEST PERFORMANCE IN GENERAL PSYCHOLOGY CLASSES.** Sheryl Darling, Robin Branche, Judy Wallace. Virginia Beach Campus, Tidewater Cmnty Col., Virginia Beach VA 23456. A study of the relationship between student test grades and: (a) actual distance from the student to the instructor, and (b) row, column, and arc seating is reported. Volunteer students ( $n = 98$ ), who selected their own seats in four Introductory Psychology classes served as subjects. Students who sat closer to the instructor received slightly higher grades than those who sat farther away. Research is preliminary and subject to more extensive future studies of classroom ecological factors which may contribute or detract from a positive learning environment.

EFFECTS OF TIME-TOGETHER, AGE, AND GENDER ON PERCEIVED MARITAL SATISFACTION. Kathryn K. Drury, Department of Psychology, Old Dominion University, Norfolk, VA 23529-0267. Effects of time-together (time spent together in marriage), age, and gender on perceived marital satisfaction were examined. Subjects in a younger unmarried group were 24 male and 24 female undergraduates ranging from 18 to 25 years and subjects in an older married group were 24 male and 24 female local residents who ranged in age from 34 to 79 years. These individuals read a scenario depicting a marriage with either high or low recreational time-together and then rated the marital satisfaction of the described couple. Analyses of variance revealed that perceived marital satisfaction was affected only by time-together. Neither gender nor age of subjects affected perceived marital satisfaction. Suggestions for additional refinements are discussed.

EFFECTS OF RETENTION INTERVAL AND NUMBER OF LANDMARKS ON THRESHOLDS FOR DETECTING SPATIAL DISPLACEMENT. Jennifer K. Gladwell, Mary Anstine,\* Kathy L. Ferrell,\* Joseph B. Thompson,\* and David G. Elmes, Dept. of Psychology, Washington and Lee Univ., Lexington, VA 24450. Recent research from our laboratory shows that humans and animals use landmarks to remember an object's location. The earlier results are consistent with a vector model of landmark representation, which was tested in the present experiments by varying the number of landmarks surrounding a target object. Also of interest was the length of the retention interval between study and test. Human subjects had to remember the location of a target in a three-dimensional computer display. Four seconds were allowed to study the target location, which was surrounded by different numbers of landmarks. Then the subjects engaged in different amounts of interfering activity before seeing the display again with the target, but not the landmarks, displaced. Subjects indicated the direction of displacement, and their threshold for detecting the direction of displacement was determined. Contrary to the vector model, the number of landmarks failed to influence thresholds in two experiments. However, in both studies increased retention interval activity elevated the thresholds for detecting the direction of displacement.

A DIME'S WORTH OF DIFFERENCE; COMPLIANCE AND NON-COMPLIANCE AT AUTOMATED TOLL BOOTHS AND DRIVER CHARACTERISTICS. C. Anthony Macera, Denise Caldwell, Timothy Jeferies, and James P. O'Brien. Social Sciences Div., Tidewater Community Col., Va. Beach Campus, Virginia Beach, VA 23455. Compliance and non-compliance at an automated toll booth on an expressway exit ramp were observed for 438 vehicles over a 5 day period, during non rush-hour traffic. Drivers of the age of 40 and over were more likely to comply. Gender and vehicle type were not discriminating variables. Vehicles with passengers complied more often than vehicles without passengers on 4 out of 5 days. Analyses of interactions and other observed characteristics is in progress. Compared with toll authority estimates of 10-12% violators, 27% of 438 vehicles failed to comply.

The Effects Of Deployment On Parenting Stress Experienced By Military Mothers Who Left Their Children Behind. Monica G. Quisenberry, Michelle L. Kelley & Peggy Simmer\*, Dept. of Psychology, Old Dominion Univ., Norfolk, VA 23529. Examined the effects of military-induced separation on the parenting stress of single (s) and married (m) female military personnel. The Parenting Stress Index (PSI: Abidin, 1983) yields two scores, the degree of stress associated with parenting and the degree of stress associated with the child. The PSI was administered to 27 (13 s, 14 m) mothers aboard a Naval supply ship stationed in Southeast, VA, approximately one month before and after a six-month deployment. Two 2 (marital status) X 2 (phase of deployment) analyses of variance were conducted on the PSI parent and child dimensions. The child stress analysis revealed no significant main effects or interaction. The parent stress analysis revealed a tendency for an interaction,  $F(1, 25) = 3.05$ ,  $p = .09$ . Single and married women reported similar levels of stress prior to deployment ( $M(s) = 182$ ,  $M(m) = 182$ ) after deployment ( $M(s) = 195$ ,  $M(m) = 181$ ) single women reported more stress. These results coupled with the fact that both groups of mothers scored above Abidin's (1983) recommended cutoff (153) before and after deployment, suggest that feelings of being overwhelmed may accompany the deployment period and that there is a need for professional assistance to address parenting needs/stress for these mothers.

WORK AND FAMILY CONFLICTS: DECISION MAKING PATTERNS OF FEMALE UNIVERSITY FACULTY AND STAFF. Cheryl L. Shiflett & R. H. Kirby, Dept. of Psychology, Old Dominion University, Norfolk, VA 23529. This study investigated the influence of lifestyle orientation of career women, their prioritization of different life values on career/family decisions, and the influence of four cues in such decision making. The study sought to detect changes in women's decisions since the earlier study of Taylor and Spencer (1988), on which this study was based. Seventy-five female university employees responded to 16 career scenarios by rating the likelihood that a woman would accept a promotion that required travel. The scenarios varied four cues -- husband's financial support, presence of a 2-year-old child, woman's career aspirations, and husband's support for the woman's career endeavors. Husband's support was the most heavily weighted cue for family-accommodated subjects. Career aspirations was the most heavily weighted for the family-directed subjects. Presence of a 2-year-old child was most heavily weighted for the career-accommodated subjects.

EFFECTS OF INTERFERENCE ON THE RETENTION OF WORDS, ICONS, AND THEIR LOCATION. Cara L. Snyder, Thomas S. Mayer,\* Joseph B. Thompson,\* and David G. Elmes, Dept. of Psychology, Washington and Lee Univ., Lexington, VA 24450. Subjects were tested in a computerized version of the game *Snitch*, in which they had to remember which of several icons or words had been "snitched" from the display, and they had to return the snatched item to its original location in the display. In a standard retroactive interference design, subjects observed a target display of words or icons, then they observed and were tested on a second display of either words or icons. Following this interference task, they were tested on the first display. Types of items (words or icons) in the target and interfering tasks were combined factorially. For the target task, icons were better remembered as having been snatched than were words. Having the same type of interference as the target task interfered more with retention of the snatched object than did different interference. Although the absolute error in replacing the targets did not differ, there was evidence that icons provided more interference than did words.

PATTERNS OF ALCOHOL USE IN A VIRGINIA COMMUNITY COLLEGE. Julie Wray, Eleanor Santos, Sue Argus, Ted Traver, and James O'Brien, Virginia Beach Campus, Tidewater Cmnty. Col., Virginia Beach, Va. 23456. The serious consequences of drug use among American undergraduates as well as regulations affecting Federal funding have led to several in depth studies of student substance use and abuse. The most widely abused substance in this population is alcohol. Is alcohol consumption in a community college population similar to that in university populations? Subjects are 211 community college students who responded willingly to survey items on alcohol use: (1) 5 percent reported no use ever; (2) 68.5 percent reported typical use (at least one occasion in the last 30 days); and (3) 27.3 percent were heavy drinkers (consumed 5 or more drinks on at least one occasion in the last two weeks). The 1990 results of the Virginia Consortium for Substance Abuse Prevention were: (1) 8 percent; (2) 77 percent; (3) 38 percent, respectively. Compared to national statistics; more subjects surveyed had used alcohol, but fewer met the criteria for typical use and heavy use.

## Statistics

EXTRAPOLATION OF HCFA MORTALITY TO ALL CASES. R. Clifton Bailey, Health Care Financing Administration, 6325 Security Blvd. Baltimore, Maryland 21207. The unit of analysis for the mortality analysis in the HCFA Hospital Information release has been one admission per person with a discharge in a given year. A person may have more than one discharge in a given year. Hence one discharge for each person is selected at random for the analysis. This paper will review this issue and present one approach for extrapolation from the random discharge to all discharges for the person. For Medicare cases at hospitals in Virginia, the HCFA analysis uses about 0.57 of the cases. The predicted mortality using the extrapolation method is very close to that obtained from the random admission.

EXPLORING THE NEAR-ROTatability OF EXPERIMENTAL DESIGNS. Karen E. Campbell and Robert E. Johnson\*, Dept. Mathematical Sciences, Va. Commonwealth Univ., Richmond, Va. 23284. Rotatability is a well known property of designs. Until recently, however, if a design was not rotatable, there was no way to know "how close" to being rotatable the design was. Several authors have recently proposed metrics to measure rotatability. One such measurement, the  $Q^*$  measurement [Draper and Pukelsheim, 1990], is an  $R^2$ -like quantity which measures the similarity between the moment matrix of a given design and the moment matrix of a rotatable design. However, this measurement does not give any indication of the magnitude or dispersion of the variance of an estimated response at some particular point, nor does it give an idea of how close to rotatable a design has to be in order to approximate the desired properties of rotatability, i.e. constant variance on spheres. Other measurements must be used to answer these questions. Those measurements proposed by Giovanetti-Jenson and Myers (1991), namely the average, maximum, and minimum variance, give a very good indication of the behavior of the variance of the estimated response. These measurements were briefly reviewed, and finally, measurements based on these, such as a scaled range and the coefficient of variation, along with the  $Q^*$  measurement, were used as the criteria to compare several different designs.

THE USE OF A PARALLEL AXIS SYSTEM TO DETERMINE PLANARITY OF DATA WITH APPLICATIONS TO THE STUDY OF CHEMICAL MIXTURES. Kathryn S. Dawson, Hans Carter, Chris Gennings, Department of Biostatistics, Va. Commonwealth Univ., Richmond, Va. 23298

In the study of mixtures of  $k$  chemicals it is often of interest to examine the  $k$ -dimensional dose surface that yields a response at a fixed level. If there are no interactions (additivity) among the  $k$  chemicals this contour of constant response, or isobol is a  $k$ -dimensional hyperplane. If interactions are present the isobol will deviate from this well defined plane of additivity. In studies of chemical mixtures with greater than three components it is difficult to visualize these  $k$ -dimensional relationships. Assuming the data satisfy the constant response being considered a nonparametric test to detect deviations from additivity will be demonstrated. In addition the use of a parallel axis system will be used to display the data and demonstrate deviations from the plane of additivity.

MODERN MODELING SOFTWARE ALLOWS ROUTINE APPLICATION OF MODERN REGRESSION METHODS. Frank E Harrell Jr\*, Division of Biometry and the Heart Center, Duke University Medical Center, Box 3363, Durham NC 27710. There is a temptation for statisticians (and even more so for non-statisticians) to lower their standards to meet the capabilities of standard statistical software packages. It seems that the more user-friendly is the software, the more rigid control it can exert on the statistician. For example, a package may make fitting a complex model easy but not allow for transformations of covariates or complex interactions to be examined. Most packages can run stepwise and all-possible-regression analyses that generate any needed number of pages of output without being burdened by the need for a hypothesis or for validation. Modern validation methods such as bootstrapping are seldom implemented fully, i.e., in such a way that penalties for all steps including stepwise variable selection are taken into account.

To allow for such facilities as coding for categorical variables, automatic tests of linearity, pooled tests of all interactions involving each predictor, automatic tests of linearity of interaction (product-form interaction), and bootstrap validation of the entire process for *any* type of regression model, a high-level statistical language is needed. This talk will focus on one such language, *S*, which is a object-oriented language that enjoys an international network of statistician implementing state-of-the-art statistical methods.

A SAS Menu-Driven System for the Current Index to Statistics. Charles W. Kish, Jr., Kathryn S. Dawson, Dept. of Biostatistics, Virginia Commonwealth Univ., Richmond, VA 23298-0032.

Since 1991, the Current Index to Statistics (CIS) computerized database has been available. The current edition has 98,634 entries covering 1978 to 1990. The records are contained in 26 IBM-PC DOS flat files on 13 high density micro diskettes. No software is provided to manage nor query the datafiles. A portable, menu-driven software system for accessing the CIS database is described. The SAS based system converts the CIS datafiles into a relational SAS database and provides windows for users to easily define their queries. Compound queries and multiple search options are available. Query execution may occur in batch or interactive mode.

ROBUST SPHERICAL REGRESSION. Daijin Ko, Dept. of Biost., Va. Commonwealth Univ., Richmond, VA 23298 & Ted Chang\*, Dept. of Math., Univ. of Va., Charlottesville, VA 22903. Robust estimators for rotation matrix in a spherical regression model are studied. M-estimators for rotation matrix and concentration parameters are introduced and their standardized influence functions as well as asymptotic distributions are derived. We give necessary and sufficient conditions under which the M-estimators become SB-robust. Optimal SB-robust M-estimators, in a sense similar to Hampel, are proposed. Finally, the data from a plate tectonic analysis of the Gulf of Aden is revisited and an influence analysis is performed.

PREDICTING THE COURSE OF DISEASE. Henry Krakauer\*, Dept. of Prev. Med. & Biometrics, Uniformed Services Univ., Bethesda, MD 20814 , & R. Clifton Bailey, Health Care Financing Admin., Baltimore, MD 21207. The time course of events (death or rehospitalization) indicating change in the state of health of individuals following their hospitalization for myocardial infarction or pulmonary disease was evaluated using the life-table method and a time-to-event multiple regression technique based on the fully parametric Bailey-Makeham model. We found that the time course could be predicted quite satisfactorily for most types of patients if their condition at the time of admission was well characterized by means of detailed clinical data. The predictions were generally stable to variations in case-mix when regressions were performed in populations formed by random sampling with replacement and applied to the parent population. We conclude that the influence of patient risk-factors and of treatments on the course of disease can be reliably modeled and the resulting data used to assist in clinical care.

CONTROL CHARTS ON THE RESIDUALS OF THE TIME-SERIES MODEL. Chao-Wen Lu and Marion R. Reynolds, Jr., Dept. of Statistics, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. In statistical process control, it is usually assumed that observations of the process output at different times are IID. Recently control charts in the presence of correlation have received much attention. This study evaluates the properties of control charts based on the residuals from the forecast values of an ARMA model. It is assumed that the process mean is a first order autoregressive (AR(1)) model and the observations are the mean plus a random error. Properties of these charts are evaluated using Markov chain approach and an integral equation approach. The performance of control charts based on the residuals is compared to the performance of control charts based on the observations.

ON QUEUEING MODELS WITH NON-STATIONARY POISSON ARRIVALS. Richard A. Meili Jr and John A. Barnes, Dept. of Mathematical Sciences, Va. Commonwealth Univ., Richmond, Va. 23284. Following a brief background on queueing models with non-stationary Poisson arrivals, some new results concerning the departure process from some infinite server models will be discussed. Specifically, some conditions will be presented which guarantee that the departure process is a stationary Poisson process. An application to inventory control will be included.

ROBUST POLYNOMIAL REGRESSION WITH AUTOCORRELATED ERRORS. Kwan Soo Park and Robert V. Foutz, Department of Statistics, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061. The Ordinary Least Squares estimators have minimum variance among all linear unbiased estimators by the Gauss-Markov theorem provided that the assumption of uncorrelated errors is met. But, if the errors are correlated, one robust procedure selects estimators that yield the Minimum Sum of Absolute Errors (MSAE). Many articles discuss the MSAE estimators for simple linear regression, but the properties of MSAE estimation for polynomial regression models have not been investigated when errors are correlated. In this paper, the properties of the MSAE estimators for the polynomial regression models are analyzed by the Monte Carlo methods and compared to the Ordinary Least Squares estimators for the case that the errors are autocorrelated.

EXPECTED RADIUS OF AN ELLIPSOID AS AN OPTIMAL DESIGN CRITERION. Donald E. Ramirez, Department of Mathematics, University of Virginia, Charlottesville VA., 22903. This paper will discuss the solution by Dunkl and Ramirez of the long-standing problem of computing the expected radius and surface measure of an ellipsoid. The expected radius of the ellipsoid associated with a linear design is a natural geometric measure of the efficiency of the design. Properties of the design criterion will be shown. This criterion has the important property of being more robust than the often-used A optimal criterion.

#### A CLASS OF MULTIVARIATE NONPARAMETRIC TESTS FOR MONOTONE TREND.

Sungsue Rheem, Dept. of Stat., Va. Polytechnic Inst. and State Univ., Blacksburg, Va. 24061-0439.

Dietz and Killeen (1981, *Journal of the American Statistical Association* **76**, 169–174) proposed a nonparametric multivariate test for monotone trend based on Kendall's  $\tau$  statistic. Daniels (1944, *Biometrika* **33**, 129–135) introduced a general class of correlation coefficients which includes Kendall's rank correlation, Spearman's rank correlation, and Pearson's product-moment correlation as special cases. Daniels discussed the properties of his class of correlation coefficients for the purpose of investigating the relation between two different correlation coefficients applied to the same data set over all possible permutations of the sample values. A new interpretation of Daniels' results enables us to construct a class of multivariate nonparametric trend tests, which includes the test of Dietz and Killeen as a particular case. A blood constituent data set is used for illustration of this methodology.

#### NEW DESIGN COMPARISON CRITERIA IN TAGUCHI'S ROBUST PARAMETER DESIGN.

Paul T. Savarese and Raymond H. Myers\*, Department of Statistics, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0439. Recently quality in American industry is receiving much attention. Academic, government, and industrial research efforts are all devoting resources to understanding the fundamental nature of quality. Among these efforts is that of "Robust Parameter Design" a phrase introduced by the Japanese engineer Genichi Taguchi. Robust Parameter Design (RPD) involves determining the levels of fixed control variables that are robust to variation transmitted by random noise variables in, say, an industrial process. A mechanism to compare competing experimental designs with regard to their ultimate performance in the RPD setting is desired. Modeled after classic alphabetic optimality criteria, new design comparison criteria are presented for use in RPD. Example comparisons of several experimental designs will be presented.

#### THRESHOLD MODELS IN RISK ASSESSMENT FOR A COMBINATION OF AGENTS

Pamela F. Schwartz, Chris Gennings, and Vern Chinchilli, Dept. of Biostatistics, Virginia Commonwealth Univ., Richmond, VA 23298-0032. Risk Assessment models for non-carcinogenic agents typically assume the existence of thresholds dose levels. A threshold model for a single agent includes a parameter for the threshold dose, i.e., the dose level at which less exposure results in only the background response and exposures above this dose level results in a dose-response trend. In a combination of two agents, the threshold is no longer a single dose value but a two-dimensional contour of dose combinations. In general for s agents, the threshold is an s-dimensional surface. It is of interest to assess the effect of the combination on the threshold surface. We propose a threshold model for combination data with model parameters which describe the threshold surface. Methods for estimation of the model parameters and creation of confidence regions about the threshold surface are developed.

#### DIAGNOSING MODELS FOR THREE-WAY DATA ARRAYS USING JOINT PLOTS.

Kyoungah See, Dept. of Statistics, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. Biplot is a method of displaying the rank 2 approximation of a matrix by plotting row vectors and column vectors. Bradu and Gabriel (1978) considered some models for a two-way layout and determined the relationship between those models and the geometry of a biplot to the data matrix. In this presentation, a graphical display of three-way table is proposed as a data analytic tool for diagnosing the type of model to fit the data. In particular, the joint plots can be used to diagnose a model looking for a pattern on the graphical display and then inferring what model that implies for the data array. Each entry of the data array is represented by a pair of vectors coming from the principal component scores - the diagnosis proceeds by examining these vectors for collinearity in a two-dimensional plane or coplanarity in a three-dimensional Euclidean space. The relationship between various models and the geometrical configurations observed from the joint plots for three-way data arrays, allow one to diagnose the type of model to fit the data.

CONTROL CHARTS WITH SEQUENTIAL SAMPLING AT EACH SAMPLING POINT. Zachary G. Stoumbos and Marion R. Reynolds, Jr., Dept. of Stat., Va. Polytechnic Inst. and State Univ., Blacksburg, Va. 24060-0439. In statistical process control, control charts are used to monitor a process to detect changes in the mean of the process that lead to low product quality. Traditional control charts use samples of fixed sample size taken at fixed sampling intervals between samples. Variable sampling interval (VSI) charts vary the interval between samples as a function of the data. Using the VSI feature in traditional control charts significantly reduces the detection time of certain changes in the mean of a process. We propose a control chart with sequential sampling, applying a sequential probability ratio test (SPRT) at each sampling point (SPRT chart), to monitor the mean of a process with a normal distribution. We use the integral equation approach to evaluate properties of the SPRT chart, such as average run length (ARL) and average time to signal (ATS). We compare the SPRT chart to VSI charts on the basis of ATS performance.

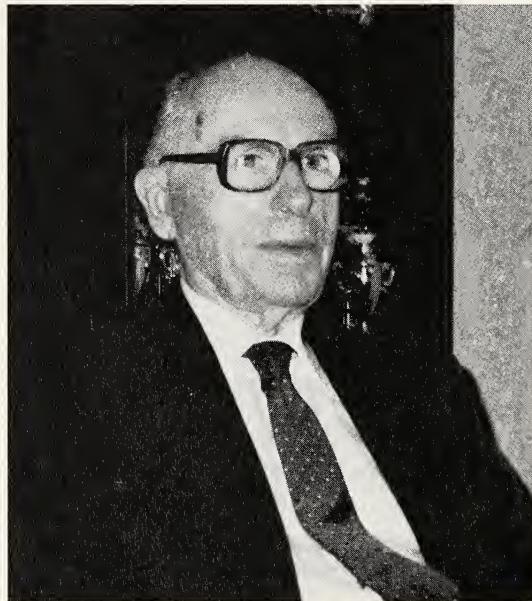
SIMULTANEOUS ESTIMATION OF GAMMA MEANS IN THE PRESENCE OF A NUISANCE PARAMETER. Patricia Pepple Williamson, Dept. of Math. Sciences, Virginia Commonwealth University, Richmond, Va. 23284-2014.

The problem of simultaneously estimating Gamma means is investigated when the parameters are believed a priori to be similar in size and the shape parameter is unknown. A hierarchical Bayes analysis is performed and a sampling based approach called Gibbs sampling is utilized to perform the necessary calculations. This procedure is then extended to the problem of simultaneously estimating Gamma means with unknown shape parameter when the means are believed a priori to satisfy an  $r$ -dimensional generalized linear model. An example is given to illustrate the proposed methodology.





**The Virginia Academy of Science  
Ivey F. Lewis  
Distinguished Service Award**



**Blanton M. Bruner**

A professional industrial chemist, talented administrator, and long time servant of the Virginia Academy of Science, Blanton Mercer Bruner has been honored by the Virginia Academy of Science by being presented with the Ivey F. Lewis Distinguished Service Award for 1992. Officers may come and go, sections may wax and wane, but, as has been said many times during Council meetings, the rock on which the Academy rests, the source of its stability, is the dedication of its Executive Secretary, Blanton Bruner.

A native of Richmond, Virginia, Mr. Bruner was graduated from the College of William and Mary in 1926 with the degree of Bachelor of Science. He joined the American Tobacco Company in 1928, working in the Department of Research and Development on such problems as the quality of paper and the analysis of maple sugar. He rose through the ranks of management to become Assistant to the Vice President of Research and Development. At the time of his retirement from this first career he was serving as Director of Technical Information and Community Relations Coordinator.

During his years with the American Tobacco Company Mr. Bruner was active in the field of public relations. He chaired the Virginia Public Relations Conference of 1955 and served as President of the Richmond Public Relations Association in 1959. He also served as the Director of the Richmond Thanksgiving Festival and Director of the National Tobacco Festival.

Always active in the Virginia Academy of Science, Blanton Bruner found in retirement a new career of service. In 1969 he joined then Executive Secretary-Treasurer Rodney C. Berry as an Associate, succeeding to the full office in 1971. He has therefore served for more than twenty years as the principal executive officer of the Academy. During that time he has established a reputation for absolute reliability. With patient good humor he has shepherded a succession of officers through their duties, reminding the forgetful and encouraging the faint-hearted.

It is a measure of the esteem in which he is held by his colleagues that Blanton Bruner has received virtually all of the honors that is in the power of the Academy to bestow. He is a Fellow of the Academy and an Honorary Life Member. He is the recipient of the Distinguished Service Award of the Virginia Junior Academy of Science. In awarding him, as well, the Ivey Lewis Distinguished Service Award of the senior Academy, we hereby recognize his competence as an executive, his even-handedness as an administrator, and his devotion to the ideals of the Virginia Academy of Science.

**ACADEMY FELLOW**



**Richard B. Brandt**

Dr. Richard B. Brandt is a Professor in the Department of Biochemistry and Molecular Biophysics at the Medical College of Virginia, Richmond, where he has been since 1970. He is an Executive Board member and Chairman of the Education Division of the Nutritional Sciences Program at the Medical College of Virginia.

He received a B.S. in Chemistry from Queens College, an M.A. in Organic Analytical Chemistry from Brooklyn College and a Ph.D. in Biochemistry from New York University.

Society Memberships include: American Association for Cancer Education; American Society for Biochemistry and Molecular Biology; American Institute of Nutrition; Society for Experimental Biology and Medicine (Past President South East Region).

He has been a member of the Virginia Academy of Sciences since 1970. He was recruited into the Academy by Dr Lynn Abbott who was at that time the Chairman of the Department of Biochemistry. He was the first Secretary of the Environmental Sciences Division, recruited by Dr Roscoe Hughes, Secretary of Medical Sciences Division 1976-78, Chairman or Co-chairman 1976-1988, Councilor 1988-1990, Secretary of the Academy 1988-89, President-elect 1989-90, President 1990-91. He received the J. Shelton Horsley Research award in 1987. Currently he is on, or chairman of, several committees of the Academy. Most recently he has obtained commitments from the Presidents of VPI, VCU and George Mason for Annual Meetings of the Academy.

His other main involvement is with the American Cancer Society: Richmond Area Board of Directors, Public Education Chairman for the Richmond Area and Co-Chairman of the State Public Education Committee, Member of the State Public Issues Committee, Member of the Board of Directors (Virginia Division). In 1989, he received the Division-Unit Volunteer Award, and in 1990 the Life Saver Award from the American Cancer Society.

His research interests include: Vitamin A in disease and -Carotene and cancer protection. He is the author of over 60 research and educational publications.

His wife Renate is a Public School librarian in Richmond. Their daughter is an actress(in Los Angeles), and both sons are Ph.D. research scientists in Biochemistry (Irvine) and Physics( Chicago).

## AWARDS PRESENTED DURING THE VIRGINIA JUNIOR ACADEMY OF SCIENCE MEETING

### AGRICULTURAL AND ANIMAL SCIENCE

Honorable Mention:	Martha C. Alter	H.B. Woodlawn
Honorable Mention:	Elaine T. Chou	The Collegiate Schools
Honorable Mention:	Susan B. Watson	Patrick Henry High School
Third Place:	Monique Nikolaus	Atlee High School
Second Place:	Jason G. Tice	Governor's School for Government and International Studies
First Place:	Sneha S. amin	Patrick Henry High School

### ANIMAL BEHAVIOR (ETHOLOGY)

Honorable Mention:	Kerry J. Audley	Bishop O'Connell High School
Honorable Mention:	Vassar D. Sumpter	Huguenot High School
Honorable Mention:	Cynthia L. Weaver	Patrick Henry High School
Third Place:	Kimberly M. Costello	Yorktown High School
Second Place:	Lance D. Wahlert	Menchville High School
First Place:	James S. Kellam	Midlothian High School

### BOTANY 'A'

Honorable Mention:	Avin S. Dwivedy	Governor's School for Government and International Studies
Honorable Mention:	Camille F. Frost	Williamsburg Middle School
Honorable Mention:	Christine M. Gibbs	Patrick Henry High School
Third Place:	Natarsha Y. Fisher	Huguenot High School
Second Place:	Tamasha D. Crouse	Southwest Virginia Governor's School
First Place:	Mohammad J. Edjlali	Yorktown High School

### BOTANY 'B'

Honorable Mention:	Kimberly A. Goode	Clover Hill High School
Honorable Mention:	Rangina Hamidi	Kenmore Middle School
Third Place:	Michelle L. Gorbutt	Central Virginia Governor's School
Second Place:	Barbara Kipeloff	Cave Spring High School
First Place:	Kenneth D. Kuhn	Williamsburg Middle School

## BOTANY 'C'

Honorable Mention:	Paul E. Nguyen	Washington-Lee High School
Honorable Mention:	Sanchia D. Patrick	Hines Middle School
Honorable Mention:	Hyejin J. Suh	Monacan High School
Third Place:	Seth E. Webster	Central Virginia Governor's School
Second Place:	Everett T. Shockley	Southwest Virginia Governor's School
First Place:	John S. Will	Wakefield High School

## CHEMISTRY 'A'

Honorable Mention:	Visha L. Bindal	Thomas Jefferson High School for Science and Technology
Honorable Mention:	Daniel C. Cho	Thomas Jefferson High School for Science and Technology
Honorable Mention:	Robert C. Conklin	Cave Spring High School
Third Place:	John A. Dooley	Thomas Jefferson High School for Science and Technology
Second Place:	Eli Chen	Thomas Jefferson High School for Science and Technology
First Place:	Justin A. Caravella	Thomas Jefferson High School for Science and Technology

## CHEMISTRY 'B'

Honorable Mention:	Michael J. Fry	Thomas Jefferson High School for Science and Technology
Honorable Mention:	Su R. Han	Gildersleeve Middle School
Honorable Mention:	Howard Y. Li	Thomas Jefferson High School for Science and Technology
Third Place:	Khan W. Li	Thomas Jefferson High School for Science and Technology
Second Place:	Judson R. Holt	Thomas Jefferson High School for Science and Technology
First Place:	Michael A. Gibson	Thomas Jefferson High School for Science and Technology

## CHEMISTRY 'C'

Honorable Mention:	Thinh H. Nguyen	Thomas Jefferson High School for Science and Technology
Honorable Mention:	Warren S. Overholt	Yorktown High School
Honorable Mention:	Chi-Jen J. Wong	Thomas Jefferson High School for Science and Technology

Third Place:	Kimberly A. Walters	Thomas Jefferson High School for Science and Technology
Second Place:	Gregory C. Yerington	Thomas Jefferson High School for Science and Technology
First Place:	Amy W. Popelish	Wilson Memorial High School

### COMPUTER SCIENCE

Honorable Mention:	Benjamin L. Barry	Yorktown High School
Honorable Mention:	William T. Laforest	Wakefield High School
Honorable Mention:	Nathan A. Stratton	Washington-Lee High School
Third Place:	John C. Dudley	Denbigh High School
Second Place:	David E. Bradley	New Horizons Governor's School
First Place:	Rex K. Min	Denbigh High School

### CONSUMER SCIENCE 'A'

Honorable Mention:	R. Danielle Bailey	Matoaca High School
Honorable Mention:	SanjaY P. Bhagchandani	Meadowbrook High School
Honorable Mention:	Colin W. Delacy	Yorktown High School
Third Place:	Cory E. Barber	Thomas Jefferson Middle School
Second Place:	Megan D. Allen	Tabb High School
First Place:	Timothy E. Brown	Governor's School for Government and International Studies

### CONSUMER SCIENCE 'B'

Honorable Mention:	Christopher G. Herbert	H.B. Woodlawn
Honorable Mention:	Charles L. Park	Swanson Middle School
Honorable mention:	Nicole M. Pettis	Matoaca High School
Third Place:	L. Daniel Holsinger	Williamsburg Middle School
Second Place:	Kimberly L. Goodman	Williamsburg Middle School
First Place:	Kristi L. Lewis	Prince George High School

### CONSUMER SCIENCE 'C'

Honorable Mention:	T. Nathan Roane	Atlee High School
Honorable Mention:	Anna S. Robertson	Swanson Middle School
Honorable Mention:	Billy Wright	Norfolk Academy
Third Place:	Jennifer L. Reid	Cave Spring High School
Second Place:	Kati G. Sharpe	H.B. Woodlawn
First Place:	Bryan G. Robertson	Central Virginia Governor's School

## EARTH AND SPACE SCIENCE

Honorable Mention:	Ernst H. Kastning, III	Radford High School
Honorable Mention:	Scott L. Rosen	Yorktown High School
Honorable Mention:	Heather L. Stevens	Yorktown High School
Third Place:	David A. Bray	Hines Middle School
Second Place:	Brian M. Green	Williamsburg Middle School
First Place:	Kevin B. Jones	Washington-Lee High School

## ENGINEERING 'A'

Honorable Mention:	Michael D. Barringer	Menchville High School
Honorable Mention:	Melanie L. Burkett	Hines Middle School
Honorable Mention:	Dean T. Gamble	Robert Frost Intermediate School
Third Place:	Jignesh K. Goda	Thomas Jefferson High School for Science and Technology
Second Place:	Andrew K. Clark	Radford High School
First Place:	David R. Derkits	Yorktown High School

## ENGINEERING 'B'

Honorable Mention	Surabhi M. Mehrotra	Tabb High School
Honorable Mention	Benjamin W. Rooker	Tabb High School
Honorable mention	Garnett E. Simmers, Jr.	Southwest Virginia Governor's School
Third Place:	Daniela Y. Wotke	Denbigh High School
Second Place:	Phillip B. Northam	Gildersleeve Middle School
First Place	Brooks Moses	Southwest Virginia Governor's School

## ENVIRONMENTAL SCIENCE 'A'

Honorable Mention:	Christina L. Clarkson	Roanoke Valley Governor's School
Honorable Mention:	Melissa C. Cutter	Maury High School
Third Place:	Matthew A Chidley	Monacan High School
Second Place:	Carolyn M. Cochran	Yorktown High School
First Place:	James H. Brashears	Governor's School for Govern- ment and International Studies

## ENVIRONMENTAL SCIENCE 'B'

Honorable Mention:	Kevin J. Davis	Monacan High School
Honorable Mention:	Jennifer L. Garnet	Meadowbrook High School
Honorable Mention:	John M. Gifford	Atlee High School
Third Place:	Lale D. Gorbudak	Roanoke Valley Governor's School
Second Place:	F. Bruce Furrow	Dinwiddie County High School
First Place:	Adam G. Florence	Thomas Jefferson High School for Science and Technology

## ENVIRONMENTAL SCIENCE 'C'

Honorable Mention:	Sarah W. Joyce	Meadowbrook High School
Honorable Mention:	Michael J. Kusiak	Maury High School
Honorable Mention:	Karen R. Leigh	Menchville High School
Third Place:	Susan F. Knight	Yorktown High School
Second Place:	Meghan J. Kline	Yorktown High School
First Place:	Alan P. Moore	Peasley Middle School

## ENVIRONMENTAL SCIENCE 'D'

Honorable Mention:	Kimberly D. Nickens	Patrick Henry High School
Honorable Mention:	Carmen D. Patrick	Denbigh High School
Honorable Mention:	Anya E. Schwender	The Collegiate Schools
Third Place:	Kristi J. Oja	New Horizons Governor's School
Second Place:	Jeffrey H. Scarano	Yorktown High School
First Place:	Joseph P. Salyards, II	Valley Baptist

## ENVIRONMENTAL SCIENCE 'E'

Honorable Mention:	Henrik K. Swanljung	Maury High School
Honorable Mention:	Stefany M. Tweed	Patrick Henry High School
Honorable Mention:	Carolyn D. White	Yorktown High School
Third Place:	Anne C. Spencer	Maury High School
Second Place:	John F. Zohn, Jr.	New Horizons Governor's School
First Place:	Eric K. Weisz	Ferguson High School

## GENETICS AND CELLULAR BIOLOGY

Honorable Mention:	Tu-Anh Bui	Swanson Middle School
Honorable Mention:	Corby A. Faye	Richmond Community High School
Honorable Mention:	Eli P. Rosen	Yorktown High School
Third Place:	F. Bruce Furrow	Dinwiddie County High School
Second Place:	Nicholas M. Dechman	Thomas Jefferson High School for Science and Technology
First Place:	Rene' D. Elms	Yorktown High School

## MATHEMATICS AND STATISTICS 'A'

Honorable Mention:	Cherith B. Bailey	Central Virginia Governor's School
Honorable Mention:	Marshall R. Cox	Dozier Middle School
Honorable Mention:	Jeffrey S. Ford	Roanoke Valley Governor's School
Third Place:	Julius C. Cogswell	Woodberry Forest School
Second Place:	Matthew P. Carter	H.B. Woodlawn
First Place:	Nelson O. Fitts	Woodberry Forest School

**MATHEMATICS AND STATISTICS 'B'**

Honorable Mention:	Charles W. Harvey	Woodberry Forest School
Honorable Mention:	James B. Smethurst	Woodberry Forest School
Honorable Mention:	Christopher K. Warren	Woodberry Forest School
Third Place:	Jeremy R. Jenkins	Matoaca High School
Second Place:	Joel T. Thomas	Woodberry Forest School
First Place:	Alexander W. St.Clair	Woodberry Forest School

**MEDICINE AND HEALTH 'A'**

Honorable Mention:	Amy E. Bates	Williamsburg Middle School
Honorable Mention:	Ann M. Chewning	Liberty Middle School
Honorable Mention:	Avi B. Gibberman	Gildersleeve Middle School
Third Place:	Sara P. Fontaine	Hines Middle School
Second Place:	Ruby Z. Afram	Swanson Middle School
First Place:	Margaret E. Bourdeaux	Roanoke Valley Governor's School

**MEDICINE AND HEALTH 'B'**

Honorable Mention:	Heather L. Hough	Cave Spring High School
Honorable Mention:	Fong T. Lui	Southwest Virginia Governor's School
Honorable Mention:	Estelle P. Perera	The Collegiate Schools
Third Place:	Elizabeth H. Kamp	Yorktown High School
Second Place:	Gayle M. Horn	Robert Frost Intermediate School
First Place:	Christopher R. Pyke	Yorktown High School

**MEDICINE AND HEALTH 'C'**

Honorable Mention:	Thomas J. Sobieski, IV	Monacan High School
Honorable Mention:	Casey R. Williams	Maury High School
Honorable Mention:	Jennifer T. Wolstenholme	Thomas Jefferson High School for Science and Technology
Third Place:	Anubha Tripathi	Mills E. Godwin High School
Second Place:	Jason A. Smith	Menchville High School
First Place:	Griffin M. Weber	Denbigh High School

**MICROBIOLOGY**

Honorable Mention:	Jocelyn A. Gibbon	H.B. Woodlawn
Honorable Mention:	Courtney C. Harper	Lloyd C. Bird High School
Honorable Mention:	Erin E. Holsinger	Yorktown High School
Third Place:	Kristin M. Beitz	Monacan High School
Second Place:	Emily C. Paulson	Ferguson High School
First Place:	Jennifer J. Casaleotto	Thomas Jefferson High School for Science and Technology

## PHYSICS 'A'

Honorable Mention:	Ryan F. Agnew	Williamsburg Middle School
Honorable Mention:	Nathan T. Czyzewski	Turner Ashby High School
Honorable Mention:	John M. Ennis	Clover Hill High School
Third Place:	Jesse S. Chawla	New Horizons Governor's School
Second Place:	Max-Louis G. Buot	Thomas Jefferson High School for Science and Technology
First Place:	Jeffrey M. Chock	Thomas Jefferson High School for Science and Technology

## PHYSICS 'B'

Honorable Mention:	Tyler F. Gray	Yorktown High School
Honorable Mention:	Julie P. Houghton	Cave Spring High School
Honorable Mention:	John P. Kowalski	Williamsburg Middle School
Third Place:	Patricia C. Kao	Clover Hill High School
Second Place:	Soeur L. Ly	Thomas Jefferson High School for Science and Technology
First Place:	Michael J. Niczyporuk	Tabb High School

## PHYSICS 'C'

Honorable Mention:	Pamela A. Parnacott	Menchville High School
Honorable Mention:	Marjorie L. Victor	E.C. Glass High School
Third Place:	Jamie L. Pauls	Hermitage High School
Second Place:	Aditya N. Seth	Thomas Jefferson High School for Science and Technology
First Place:	Steven J. Purdy	Yorktown High School

## PSYCHOLOGY - GENERAL

Honorable Mention:	Michael R. Dean	Fauquier County High School
Honorable Mention:	Tara O. Platt	J.R. Tucker High School
Honorable Mention:	Elizabeth D. Simpson	Wakefield High School
Third Place:	Jennifer R. French	New Horizons Governor's School
Second Place:	Caitlin R. Wittig	Wakefield High School
First Place:	Erica S. Campbell	Roanoke Valley Governor's School

## PSYCHOLOGY - LEARNING AND PERCEPTION 'A'

Third Place:	Jennifer D. Ferrell	William Fleming High School
First Place:	Mary M. Brinig	Bishop O'Connell High School

**PSYCHOLOGY - LEARNING AND PERCEPTION 'B'**

Honorable Mention:	Julia G. Harkin	Swanson Middle School
Honorable Mention:	Diane M. Owens	Southwest Virginia Governor's School
Honorable Mention:	Elizabeth C. Pugh	Liberty Middle School
Third Place:	Sheilandice M. Holmes	Matoaca High School
Second Place:	Markus J. Namesny	Monacan High School
First Place:	Anne R. Nester	Yorktown High School

**PSYCHOLOGY - LEARNING & PERCEPTION 'C'**

Honorable Mention:	Alison C. Stagg	Atlee High School
Honorable Mention:	Tomasz W. Turowski	Roanoke Valley Governor's School
Honorable Mention:	Mary T. Ware	Atlee High School
Third Place:	Carolyn A. Weiglein	Central Virginia Governor's School
Second Place:	Rene L. Roberts	New Horizons Governor's School
First Place:	Andrew P. Sherrod	Patrick Henry High School

**PSYCHOLOGY - SOCIAL**

Honorable Mention:	Amy M. Daugherty	Lee-Davis High School
Honorable Mention:	Christin R. McGovern	Yorktown High School
Honorable Mention:	Amy C. Osorio	Thompson Middle School
Third Place:	Benjamin W. Taylor	H.B. Woodlawn
Second Place:	Kelly L. Schrock	Central Virginia Governor's School
First Place:	Jonathan J. Thessin	Williamsburg Middle School

**ZOOLOGY**

Honorable Mention:	Allyson M. Armistead	Yorktown High School
Honorable Mention:	Susan R. Busic	Patrick Henry High School
Honorable Mention:	Yanek D. Korff	Washington-Lee High School
Third Place:	Sean M. Murray	Roanoke Valley Governor's School
Second Place:	John J. Choi	New Horizons Governor's School
First Place:	Wendy A. Lee	Menchville High School

### SPECIAL AWARDS

Major W. Catesby Jones Award is for the STS winner displaying the greatest science potential.

2nd Runner-up: (\$20) - Judson Holt, Thomas Jefferson HS for Sci & Tech  
1st Runner-up: (\$30) - Jeffrey Chock , Thomas Jefferson HS for Sci & Tech  
Winner : (\$50) - David Derkits, Yorktown High School

Botany Section Award, given by the Botany Section of the VAS, to the best paper on a botanical subject.(\$50.00)

Kevin House      Dozier Middle School

VJAS Neuroscience Awards supported by the Auxiliary of the Virginia Neurological Society are given to four outstanding papers in the field of neuroscience.(\$50.00 each).

Helen A. Fabiato - The Collegiate Schools  
John Choi - Denbeigh High School  
Frederick W. Early, III - Lee-Davis High School  
Ian Chang - Norfolk Academy

Speological Society Award given to the best paper addressing karst or topics related to speleology given by the Richmond Area speleological society. (\$50.00)

Ernst H. Kastning, III  
Radford High School

Mathematics Award for the paper that evidences the most significant contribution in the field of Mathematics.(\$50.00)

Rex K. Min  
Denbigh High School

Smith Shadomy Infectious Disease Award in honor and memory of Dr. Smith Shadomy given by the Virginia Chapter of the National Foundation of Infectious Diseases. (\$50.00)

Anubha Tripathi  
Mills E. Godwin High School

Roscoe Hughes Award for the best paper in the field of Genetics. (\$50.00)

Rene' Elms  
Yorktown High School

Russell J. Rowlett Award for the Best Research Paper of the Year. (\$50.00)

David Derkits  
Yorktown High School

The Virginia Psychological Foundation Meritorious Research Awards recognize outstanding presentations of research in the various fields of psychology.

Each award includes a prize of \$80.00.

Erica S. Campbell - Roanoke Valley Governor's School

Mary M. Brinig - Bishop O'Connell High School

Anne R. Nester - Yorktown High School

Andrew P. Sherrod - Patrick Henry High School

Jonathan T. Thessin - Williamsburg Middle School

Virginia Sea Grant College Program Award is given by the Virginia Sea Grant College Program for outstanding marine or coastal research. (\$100.00) The award will be presented by Eugene Olmi, Assistant Director of the Virginia Graduate Marine Science Consortium.

Andrew Clark - Radford High School

Health Physics Award is given by the Virginia Chapter of the Health Physcis society for outstanding research on topics related to ionizing radiation. (\$500.00)

Gregory W. Harmon - Fieldale-Collinsville High School

American Cancer Society Award - This award is to recognize outstanding science papers related to cancer research. A certificate to each and to 1st place - \$200, 2nd place \$150, 3rd place \$100, and honorable mention \$50. The local chapters of the American Cancer Society will also present a plaque to each in the fall. Representing the American Cancer Society (Virginia Division) we have Patti Fogg, Public Education Director and Dr. William L. Banks, Jr. Chairman of the Public Education Committee of the American Cancer Society (Virginia Division). They presented the awards funded by the State Public Education Committee of the American Cancer Society.

Honorable Mention: Khoan Thai  
Third Place: Gregory Harmon  
Second Place: William McKee  
First Place: Rene' Elms

Washington-Lee High School  
Fieldale-Collinsville High School  
Denbigh High School  
Yorktown High School

Trip to AJAS - AAAS Meeting for two students and two alternates for presenting outstanding papers. The 1993 meeting will be held Feb 10-15 in Boston.

winner: Anne Neste - Yorktown High School  
winner: Griffin Weber - Denbigh High School  
alternate: John Will - Wakefield High School  
alternate: Wendy Lee - Menchville High School

Honorary Membership - AAAS given to two students.

Kristin Walinski - Patrick Henry High School  
Mary Jenczewski - Midlothian High School

Honorary Membership - VAS given to one student.

Griffin Weber - Denbigh High School

E.C.L. Miller Club Award to the VJAS club having the most outstanding program for the year. (\$50.00)

Homer L. Ferguson High School, Newport News, VA  
Lia Summers, President and A.D. Barker, Sponsor

#### Bethel High School Scholarship

This \$1,000 Scholarship Award comes from the interest earned from a \$10,000 endowment contributed by the students of Bethel High School, Hampton, Va., over a two year period. Accompanying this scholarship is a rotating plaque to be displayed in the student's school for the next year. This award is based on both the students presentation and paper.

Anne Nester  
Yorktown High School

#### Frances and Sydney Lewis Environmental Scholarship

A \$12,000 scholarship (\$3,000 per year for four years) for the best effort by a student grades 9 to 12 in the field of environmental science. This scholarship is in the name of Frances and Sydney Lewis and is given by the Virginia Environmental Endowment

Rene' Elms  
Yorktown High School

VAS Science Teacher Award given to an outstanding science teacher. (\$100.00)

Joyce K. Peterson  
Swanson Middle School, Arlington, VA



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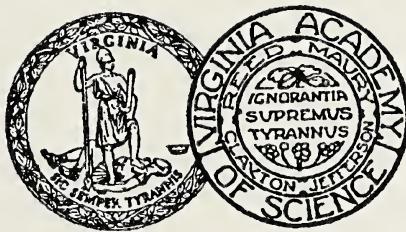
# The James River Basin *Past, Present and Future*

COMPILED BY

THE JAMES RIVER PROJECT COMMITTEE

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**James H. Martin**

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J. Sargeant Reynolds Community College

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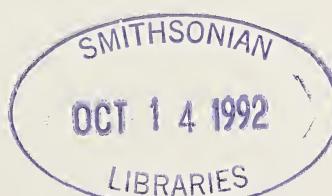
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## A Retrospective Study on the Effects of FSH and Prostaglandin on Superovulation Responses in Dairy Cattle

R. S. Canseco<sup>1</sup>, F. C. Gwazdauskas<sup>1</sup>, R. J. Toole<sup>1</sup>,  
R. Rajamahendran<sup>1</sup>, W. D. Whittier<sup>2</sup>, and W. E. Vinson<sup>1</sup>

Virginia Agricultural Experiment Station, Virginia Polytechnic  
Institute and State University, Blacksburg, VA 24061-0315

### ABSTRACT

Two hundred-eleven uterine flushings following superovulation conducted in 80 Holstein cows were examined in retrospect to assess the effects of different doses of FSH (28 to 50 mg) and prostaglandin  $F_2\alpha$  on superovulatory responses. Prostaglandin  $F_2\alpha$  (25 mg) was administered in either one or two injections. Split Prostaglandin  $F_2\alpha$  injections after FSH injection resulted in the best estrous responses (87 vs 79% estrous expression) compared to single Prostaglandin  $F_2\alpha$  injection. Split Prostaglandin  $F_2\alpha$  injections resulted in less time to estrus (55.7 h) than single Prostaglandin  $F_2\alpha$  injection (57.4 h). Estrus occurred earlier with 35 mg FSH (48h) than with 40 mg FSH (59h), 37 mg FSH (62h) or 30 mg FSH (56h). The 35 mg FSH dose resulted in more unfertilized ova than other FSH doses. Number of embryos per flush was not affected by FSH or Prostaglandin  $F_2\alpha$  injection schemes. Number of excellent and good quality embryos was not affected by dose of FSH, Prostaglandin  $F_2\alpha$  and number of times the animal was superovulated. It was concluded that estrous response and time to estrus are influenced by FSH and Prostaglandin  $F_2\alpha$  but they did not affect total number of embryos recovered or number of excellent and good quality embryos collected.

### INTRODUCTION

The use of exogenous gonadotrophins to induce superovulation in dairy cattle has been investigated by several workers. Casida et al. (1943) induced superovulation in 4 out of 7 cows by giving an FSH extract followed by an LH extract beginning on d 2 or 3 of the estrous cycle. Bellows et al. (1969) induced a high percentage of double ovulations and pregnancies in dairy cattle by using 6.25 mg of FSH over a 5 d period. In addition, Elsden et al. (1978) compared the effectiveness of FSH and pregnant mares serum gonadotropin (PMSG) to induce superovulation. They reported that FSH treated cows had more corpora lutea (CL) and resulting pregnancies than those tested with PMSG. Chupin and Procureur (1982) reported that when a total of 32 mg of FSH was administered in decreasing doses over a 4 d period, it was more effective in inducing superovulation than the same dose administered over a 5 d period. The relationship between dose of FSH and timing of administration and embryo production has been studied (Donaldson, 1984; Donaldson and Ward, 1986). The conclusion from these studies was that FSH is an important source of variation and that there was no distinct advantage of

1 Department of Dairy Science, College of Agriculture and Life Sciences

2 College of Veterinary Medicine

administering FSH over a 4 d period compared to a 5 d period or of using a decreasing dose schedule rather than an equivalent dosage schedule.

The use of prostaglandin (PG) to control reproduction in the cow has been described (Betterage, 1977). Seidel et al. (1978) reported that when PG was administered to cows which were superovulated, estrus followed sooner than when PG was administered to untreated animals. Estrus occurred at 48 h following PG in superovulated cows compared to 72 or 96 h in control cows. Also, Nelson et al. (1979) compared two time schedules (48 and 72 h after FSH administration) for administration of PG to superovulated cows. When the PG was administered at 48 h the cows had more palpable CL, but when given at 72 h after FSH administration, the cows produced more transferable embryos. Donaldson (1983) reported that when a total PG dose of 30 mg was given in 3 doses of 10 mg each, more cows showed estrus than when the same dose was given in only 2 injections of 15 mg. The objective of this retrospective study was to evaluate different doses and schedules of FSH and prostaglandin  $F_{2\alpha}$  (PGF $_{2\alpha}$ ) on superovulation response in dairy cattle.

#### MATERIALS AND METHODS

Following superovulation, a total of 211 uterine flushes were conducted on 80 Holstein cows. Before superovulation treatment rectal palpations were carried out by a veterinarian to identify reproductive unsoundness. Cows were observed for estrus twice daily and those that showed two estrous cycles of normal duration were then superovulated between d 9 and 13 of the cycle according to the FSH regimes shown in Table 1. The total FSH dose ranged from 28 to 50 mg and was administered over a 3 or 4 d period in 6 to 8 injections at 12 h intervals. Two treatments were similar except that one treatment consisted of two injections of 2.5 mg each on d 3 and 4 of the estrous cycle (Rajamahendran et al., 1987). Because of limited animal numbers in some treatments, treatments of 28, 30 and 32 mg (designated 30 mg FSH), and 40 and 50 mg (designated 40 mg) FSH were combined into pooled treatments for statistical analyses. To induce luteolysis, 25 mg of PGF $_{2\alpha}$  in either 1 (control) or 2 injections was administered starting at various times after the first FSH injection (Table 2). The first three treatments consisted of one injection given at 60, 72 or 84 h after the first FSH injection, respectively. Due to low numbers in the 84 h treatment group, all single injection groups were pooled. In the next three treatments, the total dose (25 mg) was divided into two equal injections administered 12 h apart, starting at 48, 60 and 72 h after FSH initiation. Again, because of low numbers all treatments were pooled into a single double injection group for statistical analyses. Cows in estrus were artificially inseminated at onset of estrus, 12 and 24 h later. Cows which were not seen in estrus were inseminated at 72 and 84 h after the first FSH injection. Finally, 6 d after the first insemination all the cows were subjected to nonsurgical uterine flushing to recover embryos (Rajamahendran et al., 1987), which were then graded into viable and non-viable categories (Greeve et al., 1979).

Regression analysis was used to evaluate estrus response to PG, timing to estrus, and number of ova and embryos per flush.

#### RESULTS AND DISCUSSION

Estrous response to PG was affected only by the PG regimen ( $p < 0.07$ ). Eighty-three percent of all cows exhibited estrus in response to PG. There was a

TABLE 1. FSH injection regimes.

Treatment Number	(n) <sup>1</sup>	Total Dose (mg)	Day of Superovulation <sup>2,3</sup>			
			1	2	3	4
1	4	28	5:5	4:4	3:3	2:2
2	8	30	5:5	5:5	5:5	--
3	101	32	6:6	5:5	3:3	2:2
4	44	35	5:5	5:5	5:5	5:0
5 <sup>4</sup>	31	37	6:6	5:5	3:3	2:2
6	19	40	5:5	5:5	5:5	5:5
7	4	50	7.5:7.5	7.5:7.5	5:5	5:5

<sup>1</sup>(n) number of cows superovulated.<sup>2</sup>FSH started either AM or PM.<sup>3</sup>1,2,3 or 4 refer to day 9 to 13 of the estrous cycle on which FSH injection began.<sup>4</sup>2.5 mg FSH also were given on day 3 and 4 of the estrous cycle.TABLE 2. Prostaglandin F<sub>2</sub>α (PG) injection regimens.

Treatment Number	(n) <sup>1</sup>	Total <sup>2</sup> Dose	Number of injections	Number of Hours after FSH <sup>3</sup>
1 <sup>4</sup>	57	25	1	60
2	34	25	1	72
3	4	25	1	84
4	2	25	2	48-60
5	107	25	2	60-72
6	7	25	2	72-84

<sup>1</sup>(n) number of cows superovulated.<sup>2</sup>PG started AM or PM.<sup>3</sup>Time of administration after initial FSH injection.<sup>4</sup>Treatments 1, 2 and 3 and 4, 5 and 6 were combined for statistical analysis to assess one vs two injections.

$79.2 \pm 4.5\% (\bar{x} \pm \text{SEM})$  response in terms of observed estrus for cows which received a single PG injection compared to  $86.9 \pm 4.7\%$  response for cattle injected twice with 12.5 mg PG at 12 h intervals. Our data are consistent with those of Donaldson (1984) who obtained an 86.6% response in cows given two PG injections. Under physiological conditions, a relatively short pulse of PG (every 6 h) over a period of 25 to 30 h was reported as the minimal requirement for CL regression in sheep (McCracken et al., 1984). Time to observation of estrus was influenced by PG regimen ( $p < 0.01$ ). Time to estrus following one PG injection averaged  $57.4 \pm 1.5$  h compared to  $55.7 \pm 1.6$  h for cattle injected twice with PG.

FSH regime influenced ( $p < 0.05$ ) the time to observation of estrus. Cows injected with 35 mg FSH averaged 48.4 h to onset of estrus (Table 3). This was a

shorter time interval ( $p < 0.01$ ) than all other treatments. Cows which received 2.5 mg FSH on days 3 and 4 of the estrous cycle and 32 mg FSH (37 mg) for superovulation had 5.8 h more time ( $p < 0.05$ ) before mean onset of estrus than cows given the 30 mg FSH only for superovulation. It appears that the response to the 35 mg dose of FSH may be related to a reduction in time to the onset of estrus following luteal regression with PG. Greeve et al. (1980) and Donaldson (1983) recorded intervals of 42 to 48 h to onset of estrus in synchronized cows. Seidel et al. (1978) found that time to estrus following PG was about 48 h in superovulated cows but this was increased to 60 to 72 h in single ovulation cows.

There was a significant interaction ( $p < 0.01$ ) between the FSH and PG regimens for time to onset of estrus. A single injection of PG with 37 and 40 mg FSH and a double PG injection with 30 mg resulted in a greater amount of time to the onset of estrus than the other treatments (Table 4). The double PG injection with 35 mg FSH resulted in a shorter interval to estrus than double PG injections with 37 and 30 mg FSH and all single PG injections.

The total number of embryos per flush was not affected by day of FSH initiation, FSH injection regime, PG injection scheme or number of superovulations to which the cow had been subjected ( $p > 0.10$ ). The average number of embryos per flush was 7.9 for all cows. Table 5 shows the number of embryos per flush for each FSH regimen. Our data are in contrast to others who have found differences in superovulatory response to the injection regime (Garcia et al., 1982; Hill et al., 1985; Looney et al., 1981) and day of the cycle on which FSH treatment was initiated (Donaldson, 1984; Lerner et al., 1986; Lindsell et al., 1986). The total embryos per flush agrees with Rajamahendran et al. (1987) and is higher than that reported by Looney et al. (1981).

The mean number of unfertilized ova ( $1.4 \pm 0.3$ ) per flush was not affected ( $p > 0.10$ ) by day of FSH initiation, PG injections or number of superovulations, but was affected by FSH dose (Table 5). The 35 mg FSH dose resulted in the highest number of unfertilized ova. The overall fertilization rate of 83% is in agreement with reported fertilization rates of 70 to 85% (Elsden et al., 1978; Sreenan and Diskin, 1982).

The number of embryos classified as excellent or good was not affected by FSH regimen ( $p > 0.10$ ), PG regimen ( $p > 0.10$ ) and number of times cows were superovulated ( $p > 0.10$ ). The number of excellent and good embryos ( $4.5 \pm 4.5$ ) was lower than that reported by Lindsall et al., (1986), but greater than that of Garcia et al. (1982). Lerner et al., (1986) have reported decreased embryo quality and reduced numbers of transferable embryos with increasing donor age and increased number of transferable embryos with higher doses of FSH. They speculate that age related changes in embryo numbers and quality could be due to reduced numbers of growing follicles or stage of development of follicles at the time of FSH stimulation not being compatible with endocrine and gonadotrophin profiles of younger animals. Pregnancy rates of excellent and good quality embryos increase with initial embryo quality score (Coleman et al., 1987).

In conclusion, a greater percentage of cattle receiving PG in two injections were observed in estrus than those receiving one PG injection. While time to observe estrus was less in cattle receiving two PG injections than with one injection, total number of embryos recovered per flush, number of unfertilized ova and number of

TABLE 3. Hours to estrus by FSH treatment.

FSH Dose (mg)	$\bar{x}$	Time (h) <sup>1</sup>	(n) <sup>2</sup>
		SE	
30	56.3	1.2 <sup>ad</sup>	97
35	48.4	1.9 <sup>b</sup>	37
37	62.1	2.6 <sup>ac</sup>	26
40	59.4	3.1 <sup>a</sup>	16

<sup>1</sup> Least squares means and SE.<sup>2</sup> Number of cows observed in estrus.a-d means with different superscripts differ ( $p < 0.05$ ).TABLE 4. Hours to estrus in cows injected with different doses of FSH and one or two injections of Prostaglandin F<sub>2</sub> $\alpha$ (PG).

FSH Dose (mg)	PG injection regimen <sup>1</sup>	
	1 Injection	2 Injections
30	54.7 $\pm$ 1.7 <sup>bd</sup>	57.6 $\pm$ 1.6 <sup>a</sup>
35	57.8 $\pm$ 3.6 <sup>bd</sup>	45.3 $\pm$ 2.1 <sup>bc</sup>
37	67.5 $\pm$ 5.3 <sup>a</sup>	55.5 $\pm$ 4.1 <sup>bd</sup>
40	67.5 $\pm$ 3.5 <sup>a</sup>	— —

a-d means with different superscripts differ ( $p < 0.05$ ).<sup>1</sup> Least squares means and SE.TABLE 5. Least squares mean  $\pm$  SE number of embryos and unfertilized ova (UFO) per flush by FSH dosage.

FSH Dose (mg)	Number of Embryos		Number of UFO	
	$\bar{x}$	SE	$\bar{x}$	SE
30	8.4	0.8	1.1	0.4 <sup>a</sup>
35	9.6	1.3	3.7	0.6 <sup>b</sup>
37	7.8	1.8	0.7	0.9 <sup>a</sup>
40	5.9	2.0	0.3	1.0 <sup>a</sup>

a,b Means with different superscripts differ ( $p < 0.01$ ).

embryos classified as excellent or good were not affected by PG. The 35 mg FSH resulted in earlier estrous manifestation and more unfertilized ova than other treatments. But number of embryos recovered, and number of excellent and good embryos were not affected by FSH treatment. These data suggest that a wide

variety of FSH doses and PG treatments can be used for successful superovulation and estrous synchronization in dairy cattle.

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#### LITERATURE CITED

- Bellows, R.A., D.C. Anderson, and R.E. Short. 1969. Dose-response relationships in synchronized beef heifers treated with follicle stimulating hormones. *J. Anim. Sci.* 28:638-644.
- Betteridge, K.J. 1977. Embryo Transfer in Farm Animals. Canada Department of Agriculture, Ottawa. pp 1-5.
- Casida, L.E., R.K. Meyer, W.H. McShan, and W. Wisnicky. 1943. Effect of pituitary gonadotropins on the ovaries and induction of superovulation in cattle. *Am. J. Vet. Res.* 4:76-79.
- Chupin, D., and R. Procureur. 1982. Use of pituitary FSH to induce superovulation in cattle. Effect of injection regime. *Theriogenology* 23:81 (Abstr.).
- Coleman, D.A., R.A. Dailey, R.E. Leffel, and R.D. Baker. 1987. Estrous synchronization and establishment of pregnancy in bovine embryo transfer recipients. *J. Dairy Sci.* 70:858-866.
- Donaldson, L.E. 1983. The effect of prostaglandin F2 alpha treatments in superovulated cattle on estrus response and embryo production. *Theriogenology* 20:279-285.
- Donaldson, L.E. 1984. Dose of FSH-P as a source of variation from superovulated cows. *Theriogenology* 22:205-211.
- Donaldson, L.E. 1984. The day of the cycle that FSH is started and superovulation in dairy cattle. *Theriogenology* 22:97-99.
- Donaldson, L.E., and D.N. Ward. 1986. Superovulation in cattle: Dose response to FSH-W with and without LH contamination. *Theriogenology* 25:747-757.
- Eldsen, R.P., L.D. Nelson, and G.E. Seidel, Jr. 1978. Superovulating cows with follicle stimulating hormone and pregnant mare's serum gonadotropin. *Theriogenology* 9:17-26.
- Garcia, G.J.K., G.E. Seidel, Jr., and R.P. Eldsen. 1982. Efficacy of shortened FSH treatment for superovulating cattle. *Theriogenology* 17:90 (Abstr.).
- Greeve, T., H. Callensen, and P. Hyttel. 1980. Plasma progesterone profiles and embryo quality in superovulated dairy cows. *Theriogenology* 21:23 (Abstr.).
- Greeve, T., H. Lehn-Jensen, and N.O. Rasbek. 1979. Morphological evaluation of bovine embryos recovered non-surgically from superovulated dairy cows. *Ann. Biol. Anim. Biochem. Biophys.* 19:1599-1611.
- Hill, K.G., C.W. McFarland, R.W. Rorie, S.D. Viker, and R.A. Godke. 1985. A single 50 mg injection of follicle stimulating hormone (FSH) for superovulation of embryo donor cattle. *Theriogenology* 23:1 (Abstr.).

- Lerner, S.P., W.V. Thayne, R.D. Baker, T. Henschen, S. Meridith, E.K. Inskeep, R.A. Daily, P.E. Lewis, and R.L. Butcher. 1986. Age, dose of FSH and other factors affecting superovulation in Holstein cows. *J. Anim. Sci.* 63:176-183.
- Lindsell, C.E., V. Pawlyshyn, A. Bielanski, and R.J. Mapletoft. 1986. Superovulation of heifers with FSH-P beginning on four different days of the cycle. *Theriogenology* 26:209-219.
- Looney, C.R., B.W. Boutte, L.F. Archbald, and R.A. Godke. 1981. Comparison of once daily and twice daily FSH injections for superovulating beef cattle. *Theriogenology* 15:13-22.
- McCracken, J.A., W. Schramm, and W.C. Okulicz. 1984. Hormone receptor control of pulsatile secretion of PGF2-alpha from the ovine uterus during luteolysis and its abrogation in early pregnancy. *Anim. Reprod. Sci.* 7:31-55.
- Nelson, L.D., G.E. Seidel, Jr., R.P. Elsden, and R.A. Bowen. 1979. Superovulation of cows using follicle stimulating hormone and prostaglandin F2. *Theriogenology* 11:104 (Abstr.).
- Rajamahendran, R., R.S. Canseco, C.J. Denbow, F.C. Gwazdauskas, and W.E. Vinson. 1987. Effect of low dose of FSH given at the beginning of the estrous cycle and subsequent superovulatory response in Holstein cows. *Theriogenology* 28:59-65.
- Seidel, G.E., Jr., S.M. Seidel, and R.A. Bowen. 1978. Bovine embryo transfer procedures. Colorado State Experiment Station. Bull. No. 975. Fort Collins, CO. pp 1-40.
- Sreenan, J.M., and M.G. Diskin. 1982. Current efficiency in embryo transfer technology and its role in cattle breeding. *Irish Vet. J.* 36:138-144.



## Variation in Acetylene-reduction (Nitrogen-fixation) Rates in *Reticulitermes* spp. (Isoptera; Rhinotermitidae)

Snehlata Pandey, Deborah A. Waller<sup>1</sup> and Andrew S. Gordon,  
Department of Biological Sciences, Old Dominion University,  
Norfolk, VA 23529, USA

### ABSTRACT

Using the acetylene-reduction assay, we examined nitrogen fixation in ten colonies of species of *Reticulitermes* Holmgren in Virginia. Colonies varied significantly in rates of acetylene reduction, but there was no clear association between rate and termite biomass. Ethylene production (nitrogen fixation) was significantly greater during the first 30 minutes of the assay than for subsequent periods, indicating that samples should be tested within the first hour of incubation. Based on acetylene-reduction rates measured in this study and on colony size determinations by Grace (1990), we estimate that *Reticulitermes* colonies are capable of fixing 0.01-0.04 g nitrogen/m<sup>2</sup>/year, or 125.5 - 445.3 g nitrogen/ha/year.

### INTRODUCTION

Termites may be a significant source of nitrogen in the terrestrial environment because of their hindgut bacteria that fix atmospheric nitrogen (Breznak et al., 1973; Potrikus and Breznak, 1977; Waughman et al., 1981). Bentley (1984) demonstrated that fixed nitrogen is incorporated into termite tissues, but it is unknown whether the amount of nitrogen fixed is substantial enough to contribute to termite nitrogen budgets. Nitrogen fixation activity varies widely among termite species (Breznak, 1984; Waller and La Fage, 1987), termite castes (Prestwich et al., 1980; Hewitt et al., 1987), termites of different biomass (Waller et al., 1989) and levels of dietary nitrogen (Breznak et al., 1973; Prestwich et al., 1980).

Some of the variation reported for nitrogenase levels is related to assay timing, because fixation rates decrease soon after collection for some species. Prestwich et al. (1980) noted that nasute termites (Nasutitermitinae) fix significantly less nitrogen when confined with nest materials in a plastic bag for 24 hours. Lovelock et al. (1985) found that nitrogen fixation rates decrease in nasutes both in the laboratory and in containers at the nest site. Nitrogen fixation rates may also decline during the assay, but the decrease has not been quantified for any termite species.

In this study we investigated nitrogen fixation in the subterranean termite species of the genus *Reticulitermes* (Rhinotermitidae), important economic pests in the United States (Su and Scheffrahn, 1990). We examined variation in fixation rates among colonies by using the acetylene-reduction assay, a common method for measuring nitrogenase activity (Hardy et al., 1973; Breznak et al., 1973; Prestwich et al., 1980). In this assay, termites are incubated with acetylene, which is reduced to ethylene by the nitrogenase enzyme. Ethylene production is therefore a measure of nitrogenase activity. We examined nitrogenase activity several times

<sup>1</sup> Correspondence to: Deborah Waller, Department of Biological Sciences, Old Dominion University, Norfolk, VA 23529, USA

during the assay to quantify variation in fixation rates during the incubation period. From the results we determined the most appropriate sampling regime and made a preliminary estimate of the amounts of nitrogen that can be fixed by *Reticulitermes* colonies.

## METHODS AND MATERIALS

### Termites

*Reticulitermes*-infested logs were collected from ten different locations near Norfolk, Virginia, during May and June 1990. Logs were placed in plastic bags and maintained in the laboratory at 22-24°C. Time constraints made it impossible to collect termites and perform bioassays on the same day. Therefore, nitrogenase activity may have been reduced during storage. Termites were removed from the logs immediately before the nitrogenase assays.

### Acetylene-reduction assay

Three replicate samples from each termite colony were assayed using the acetylene-reduction technique. For each sample, fifty termite workers were isolated from the log and weighed to 0.1 mg, using an analytical balance. The termites were then placed in an 8.5 ml serum vial with an air-tight septum sleeve cap, and 1.0 ml air was removed from the vial. We then added 1.0 ml reagent-grade acetylene ( $C_2H_2$ ) to produce an atmosphere of 12%  $C_2H_2$ . Vials were incubated at room temperature and 200  $\mu l$  gas aliquots were removed at different times for analysis with a Varian® 3600 gas chromatograph equipped with flame ionization detector and a Porapak® N column which was maintained at 70°C with  $N_2$  as the carrier gas. Analyses were performed immediately following sample collection. For six of the colonies, gas samples were removed after 30 minutes, 240 minutes, and 330 minutes. For four of the colonies, gas samples were removed after 30 minutes, 185, minutes and 270 minutes. By sampling two groups of colonies at different times we were able to measure acetylene-reduction rates over five incubation periods. It was not possible to sample all ten colonies for each incubation period because of the time required to perform the bioassays. Pilot studies indicated that incubation periods of under 30 minutes frequently did not yield measurable amounts of ethylene. Amounts of ethylene produced in these assays served as a measure of nitrogen fixation rates, because the nitrogenase enzyme reduces acetylene to ethylene ( $C_2H_4$ ) at a rate three times greater than it reduces dinitrogen to ammonia (Bentley, 1984). For each colony, one sample with termites but no acetylene was examined for spontaneous production of ethylene, and vials containing acetylene but no organisms were sampled for ethylene contamination. Ethylene production was calculated as  $\mu g C_2H_4$  per gram termite fresh biomass per day.

### Analysis

Variation in nitrogenase activity among colonies and over time (30 minutes and 240-270 minutes) was analyzed with repeated measures analysis of variance (STAT-VIEW). The association between termite biomass and the rate of ethylene production at 30 minutes and at 240-270 minutes was examined with regression analysis.

## RESULTS

Colonies varied significantly in rates of nitrogen fixation for all sample periods ( $p = 0.0001$ ) (Figs. 1, 2). There were significant differences in fixation rate over

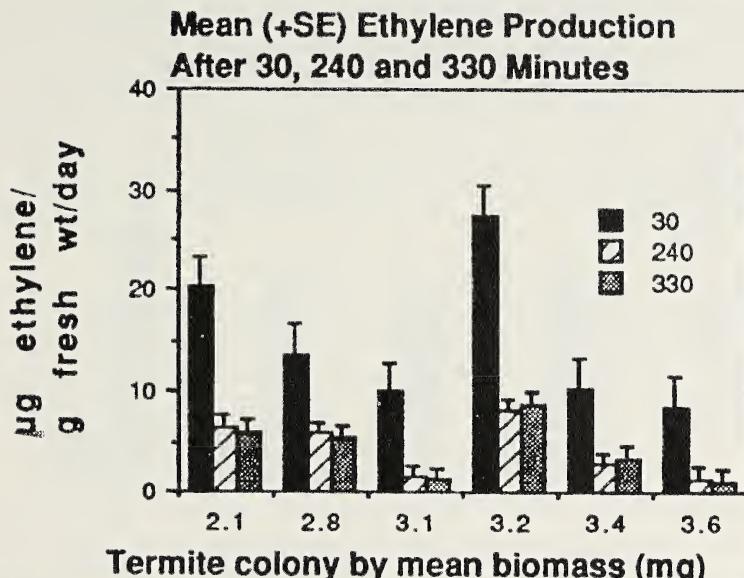


FIGURE 1. Ethylene production by six *Reticulitermes* colonies after incubation with acetylene for 30, 240, and 330 minutes. Mean worker biomass is listed for each colony.

time ( $p = 0.0001$ ), and a significant interaction between colony source and sample timing ( $p = 0.0014$ ). The acetylene-reduction rates measured at 30 minutes were almost four times greater than those at 240-270 minutes for some colonies (Figs. 1, 2). Fixation rates decreased after 185 minutes for the four colonies tested then (Fig. 2), and remained constant through the 330 minute sample for the other colonies (Fig. 1).

There was no association between termite biomass and nitrogenase activity at 30 minutes ( $p = 0.1901$ ,  $R^2 = 0.094$ ), and only a weak association at 240-270 minutes ( $p = 0.0137$ ,  $R^2 = 0.293$ ) (Figs. 1, 2).

We calculated the potential amount of nitrogen fixed by *Reticulitermes* by using the estimate of Grace (1990) of almost one million *R. flavipes* individuals per colony in Toronto. With our measure of *Reticulitermes* fresh biomass at approximately 3.5 mg per individual, termites could fix 3.6-12.7 g nitrogen/colony/year at rates measured at 30 minutes in our study. Grace (1990) found that one colony covered 285 m<sup>2</sup> in Toronto; at this density, termites could fix 0.01-0.04 g nitrogen/m<sup>2</sup>/year, or 125.5-445.3 g nitrogen/ha/year. This estimate reflects potential rates based on the highest rates measured in our study. Natural levels of nitrogenase activity are still unknown.

#### DISCUSSION

This study documents significant variation in nitrogen fixation rates among *Reticulitermes* colonies in Virginia. Rates differed over three-fold for some colonies. Waller et al. (1989) also found significant variation in nitrogen fixation rates among colonies of *Coptotermes formosanus* Shiraki (Rhinotermitidae) in Louisiana. In both studies, colony variation might have been related to differences in the food or in colony age or vitality. In addition, the taxonomy of *Reticulitermes*

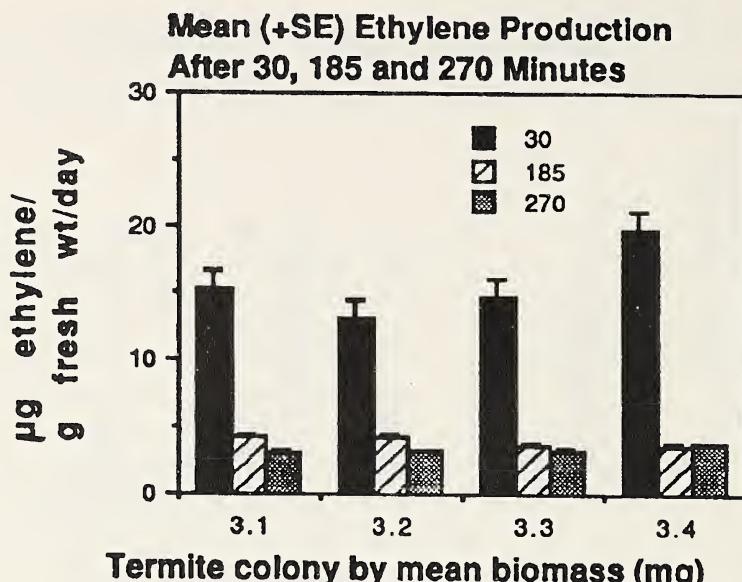


FIGURE 2. Ethylene production by four *Reticulitermes* colonies after incubation with acetylene for 30, 185, and 270 minutes. Mean worker biomass is listed for each colony.

warrants revision (Margaret Collins, personal communication), and there may have been genetic differences among the colonies tested in the present study. There was no association between termite biomass and nitrogen fixation rate after 30 minutes of incubation with acetylene. A weak negative association was evident after 240 minutes, but termite biomass explained less than 30% of the observed variation. In contrast, *C. formosanus* nitrogen fixation rates increase with mean termite biomass (Waller et al., 1989). Termite size differences may be related to genetic differences, termite age or nutritional status. The importance of termite size in the magnitude of nitrogen fixation remains unclear but requires further study if valid estimates of termite nitrogen contributions are to be made.

Rates of ethylene production dropped rapidly after 30 minutes of incubation with acetylene, possibly as a result of decreased termite vitality when confined with acetylene. Our results indicate that future assays should be made within the first hour of incubation, and efforts should be made to assay the termites under the most natural conditions possible (Prestwich and Bentley, 1981).

Our estimate of the potential amounts of nitrogen that can be fixed by *Reticulitermes* suggests these insects may be an important source of nitrogen in forest habitats. Estimated contributions by *Reticulitermes* of 125.5-445.3 g nitrogen/ha/year are higher than those reported for the desert termite *Gnathitermes tubiformans* (Buckley) (Termitidae) of 66 g/ha/year (Schaefer and Whitford, 1981), but we did not consider seasonal variation in our study. Our estimates are conservative, because we did not measure nitrogen fixation directly in the field, and natural nitrogen fixation rates may be higher. Earlier measures of nitrogen fixation by *Reticulitermes flavipes* Kollar were much lower than those obtained in our study (Breznak et al., 1973; Breznak, 1984), perhaps in part because the termites were

not freshly collected. Our estimates rely on the assumption that colony size in Virginia is similar to those reported for Toronto (Grace et al., 1989; Grace, 1990). Grace et al. (1989) found *R. flavipes* colony size to be 2.1-3.2 million, with average foraging range of 266 m<sup>2</sup>. Grace (1990) measured colony size at 722,679-943,237 with a foraging range of 285 m<sup>2</sup>. Accurate estimates of termite colony size and density throughout their range, along with measures of natural nitrogen fixation rates throughout the year, are needed to provide reliable estimates of termite nitrogen contributions.

#### ACKNOWLEDGMENTS

SP was primarily responsible for performing the bioassays; SP, DAW and ASG collaborated jointly on experimental design and data analysis and interpretation. SP thanks her family for their untiring support and love during the research. This work was funded in part by a grant from the Old Dominion University Faculty Summer Research Awards to DAW.

#### LITERATURE CITED

- Bentley, B. L. 1984. Nitrogen fixation in termites: Fate of newly fixed nitrogen. *Journal of Insect Physiology* 30:653-655.
- Breznak, J. A. 1984. Biochemical aspects of symbiosis between termites and their intestinal microbiota. In Anderson, J. M., Rayner, A. D. M. (eds.) *Insect-Microbial Interactions*. Cambridge Univer. Press, Cambridge, U.K. pp. 173-203.
- Breznak, J. A., W. J. Brill, J. W. Mertins and H. C. Coppel. 1973. Nitrogen fixation in termites. *Nature* 244:577-580.
- Grace, J. K. 1990. Mark-recapture studies with *Reticulitermes flavipes* (Isoptera: Rhinotermitidae). *Sociobiology* 16:297-303.
- Grace, J. K., A. Abdallay and K. R. Farr. 1989. Eastern subterranean termite (Isoptera: Rhinotermitidae) foraging territories and populations in Toronto. *Canadian Entomologist* 121:551-556.
- Hardy, R. F. W., R. L. Burns and R. D. Holsten. 1973. Applications of the acetylene-reduction assay for measurement of nitrogen fixation. *Soil Biology and Biochemistry* 5:47-81.
- Hewitt, P. H., M. C. Van der Westhuizen, T. C. De K. Van der Linde and R. A. Adam. 1987. Acetylene reduction by the harvester termite *Hodotermes mossambicus* (Hagen). *Journal of the Entomological Society of South Africa* 50:513-520.
- Lovelock, M., R. W. O'Brien and M. Slaytor. 1985. Effects of laboratory containment on the nitrogen metabolism of termites. *Insect Biochemistry* 15: 503-510.
- Potrikus, C. J. and J. A. Breznak. 1977. Nitrogen-fixing *Enterobacter agglomerans* isolated from guts of wood-eating termites. *Applied Environmental Microbiology* 33:392-399.
- Prestwich, G. D. and B. L. Bentley. 1981. Nitrogen fixation in intact colonies of the termite *Nasutitermes corniger*. *Oecologia* 49:249-251.
- Prestwich, G. D., B. L. Bentley and E. J. Carpenter. 1980. Nitrogen sources for neotropical nasute termites: Fixation and selective foraging. *Oecologia* 46: 397-401.

- Schaefer, D.A. and W.G. Whitford. 1981. Nutrient cycling by the subterranean termite *Gnathotermes tubiformans* in a Chihuahuan desert ecosystem. *Oecologia* 48:277-283.
- Su, N. Y. and R. H. Scheffrahn. 1990. Economically important termites in the United States and their control. *Sociobiology* 17:77-94.
- Waller, D. A. and J. P. La Fage. 1987. Nutritional ecology of termites. In F. Slansky, Jr. and J. G. Rodriguez (eds.) *The Nutritional Ecology of Insects, Mites and Spiders*. John Wiley and Sons, New York. pp. 487-532.
- Waller, D. A., G. A. Breitenbeck and J. P. La Fage. 1989. Variation in acetylene reduction by *Coptotermes formosanus* (Isoptera: Rhinotermitidae) related to colony source and termite size. *Sociobiology* 16:191-196.
- Waughman, G. J., J. R. J. French and K. Jones. 1981. Nitrogen fixation in some terrestrial environments. In J. W. Broughton (ed.) *Nitrogen Fixation*. Vol 1, Clarendon Press, Oxford. pp. 104-134.

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## Adolescents' Perceptions of Scientific Occupations

Ashton D. Trice and Lana Powers-Breese,

Department of Psychology, Mary Baldwin College,  
Staunton, VA 24401

### ABSTRACT

Four-hundred-seventeen ninth and twelfth grade students in Virginia were surveyed about their perceptions of three scientific careers (biology, chemistry, and psychology) and three control occupations. Substantial inaccuracies, lack of information about careers in science, and stereotypic impressions about scientific work recommend attention to providing students with accurate information about careers in science.

### INTRODUCTION

A number of recent reports have suggested that within a generation, there will be a shortfall of half a million scientists in the United States (ETS, 1988; IAEEI, 1988; NSF, 1983). Although much of the responsibility for this shortfall is attributed to inadequate training in science and mathematics in the primary and secondary schools (Hawkins, 1990), there are clearly other factors which lead to the nonselection of scientific careers and courses of study. One important factor is the affective nature of science classes. In their analysis of the responses to the affective component of the National Assessment of Educational Progress in Science, Yager and Penick (1984) found that few adolescents reported that their science teachers take a personal interest in them or encourage them, and less than half of the 13-year-olds and fewer than a third of the 17-year-olds like going to science class or think that science class is fun.

Another potential contributor to the avoidance of science careers is whether adolescents have accurate concepts and positive perceptions about the nature of scientific occupations. Most of the research in the area of adolescents' perceptions of science is derived from a classic paper by Meade and Metraux (1957) in which it was found that high school students stereotyped scientists as being smart, elderly, always reading and making notes, looking for sudden solutions, working in a laboratory setting, and doing work that is dangerous for the scientist himself and for society at large. This work was closely replicated with highly similar findings by Beardslee and O'Dowd (1961), extended to younger children by Lowery (1967), and Ashton and Meredith (1969) found similar stereotypes among British students.

The present paper examines whether such stereotypes of the scientist still exist and extends the study of the scientist's "personality," by including questions related to adolescents' knowledge and perceptions of aspects of scientific occupations.

### METHOD

#### Subjects

Questionnaires were administered to 417 students, drawn from college-bound and advanced placement English classes in three Virginia school systems (one urban [ $N = 167$ ], one rural [ $N = 122$ ], and one small city [ $N = 138$ ] ), approximately the same number from the 9th ( $N = 221$ ) and 12th ( $N = 196$ ) grades. It was decided to survey English classes in order to obtain a representative sample of college-

bound students, as all students take English each year, while science and mathematics courses are elective during the 12th grade.

#### Measurement

The first part of each survey asked students to check which of 15 characteristics applied to six occupations, three scientific (chemist, biologist, and psychologist) and three nonscientific (police officer, politician, and astronaut). A yes/no response format was used. The phrasing used for these characteristics were: "makes a good salary," "needs to go to college," "works hard," "is honest," "is smart," "needs to know math," "is considered a scientist," "reads a lot," "writes a lot," "is kind," "is good looking," "is strong," "is brave," "is most likely a man," and "is most likely young." The second part of the survey asked students to write brief descriptions of what persons from the six occupations do "when they go to work." Age, sex, and career aspiration demographic information was also collected. Twelfth grade students were asked to list the science and math courses in which they were currently enrolled.

#### RESULTS AND DISCUSSION

Table 1 shows the overall results of Part I of the surveys. All traits were compared using the  $\chi^2$  statistic. Because of multiple comparisons, the 0.01 level of significance was used. Significant differences were found for all traits across the six occupations.

Comparisons of traits were also made by age and sex of respondents. No significant differences between boys and girls were observed at the .01 level among the three scientific occupations. Table two reports age differences for the three scientific occupations. Here a single comparison was significant at the 0.01 level (fewer 12th grade students indicated that chemists were kind than 9th grade students). That there was little change is not surprising in light of Chambers (1983) study which found that stereotyping of scientists is well established by second and third grade. There were significant differences related to age and in the three comparison professions (e.g., honesty ratings increase with age for police and decreased for politicians; boys and girls had significantly different ratings of sex-type in politicians and astronauts).

The lack of change in perceptions of scientific professions over age would be of little concern if the perceptions of the younger students were accurate. In general, however, neither the younger nor the older college-bound students provided particularly accurate descriptions for the scientific professions. The majority of students did not view reading and writing as important parts of any of the scientists' roles. While mathematics was viewed as part of the chemist's occupation/training by 87% of the respondents, only 45% of the students indicated that biologists needed mathematics and only 38% said that psychologists needed mathematics. Seventeen percent of the students did not believe that a chemist needed a college education. While 84% of students indicated that psychologists should be kind, only 29% considered them scientists, and only 49% indicated one had to be smart to be a psychologist.

A majority of students believed chemists, police, politicians, and astronauts "made a good salary," while less than half felt psychologists or biologists did so. Fewer students believed that scientists worked hard, compared to police and

TABLE 1. Percent of students answering "yes" to which characteristic applied to an occupation.(Occupations were PSY-Psychologist, CHE-Chemist, BIOL-Biologist, AST-Astronaut, POLI- Police officer, POLT-Politician)

CHARACTERISTIC	OCCUPATION					
	PSY	CHE	BIOL	AST	POLI	POLT
1. Good salary	47	85	43	71	59	92
2. Needs college	97	83	96	93	27	44
3. Works hard	67	59	69	77	74	33
4. Is honest	85	92	81	90	66	28
5. Is smart	49	88	62	71	41	27
6. Needs math	38	87	45	39	21	19
7. Is a scientist	29	99	99	72	3	4
8. Reads a lot	40	38	44	32	28	55
9. Writes a lot	32	34	45	12	44	51
10. Is kind	84	55	64	50	40	9
11. Is good looking	34	33	41	78	26	61
12. Is strong	23	20	34	60	91	17
13. Is brave	41	16	60	97	77	12
14. Is a man	14	28	20	33	45	77
15. Is young	22	27	21	44	38	16

TABLE 2 Comparison of the percentages of 9th and 12th grade students answering "yes" for characteristics which applied to scientific occupations.

CHARACTERISTIC	OCCUPATION					
	PSYCHOLOGIST		CHEMIST		BIOLOGIST	
	9th	12th	9th	12th	9th	12th
1. Good salary	51	43	83	88	40	46
2. Needs college	95	99	79	87*	95	96
3. Words hard	64	70	55	63	66	73
4. Is honest	88	83	92	91	85	78
5. Is smart	55	45	87	88	60	64
6. Needs math	33	43*	85	88	44	45
7. Is a scientist	27	32	98	100	99	100
8. Reads a lot	36	44*	36	40	43	45
9. Writes a lot	28	34	33	35	42	48
10. Is kind	80	88	61	49**	63	66
11. Is good looking	30	37	32	34	39	43
12. Is strong	24	21	18	24	30	38
13. Is brave	43	39	14	18	55	66*
14. Is a man	17	11	30	27	22	17
15. Is young	19	25	25	28	20	22

\*\* p < 0.01.

\* p < 0.05.

TABLE 3. Most Frequent Descriptions of Work Activities. [Numbers in parentheses are the percent of responses which included these descriptions.]

**Chemist**

1. Works in a factory (23)
2. Makes drugs (20)
3. Mixes chemicals (18)
4. Makes cosmetics/perfume (17)

**Biologist**

1. Finds cures for/treats diseases (20)
2. Studies marine mammals/fish (19)
3. Watches other animals (17)
4. Looks through microscopes (15)

**Psychologist**

1. Listens to people's problems (42)
2. Helps people solve problems (16)

**Astronaut**

1. Flies around in space (33)
2. Prepares to fly around in space (28)

**Police**

1. Arrests people (30)
2. Solves crimes (22)
3. Directs traffic (16)
4. Hassles people (12)

**Politician**

1. Lies (37)
2. Makes speeches (17)
3. Writes laws (11)

astronauts. It is worth noting, however, that scientific careers were less male-sex-stereotyped than the comparison occupations.

Thirty-seven students indicated that they planned to pursue a scientific career (10 biology, 4 chemistry, 2 physics, 3 "scientist," 5 engineers, and 13 psychology); 12 students indicated an interest in a career involving computers; and 23 students planned on careers in health care. It is of some interest that there were no differences in the percentage of seniors planning science-related careers ( $N = 34$ ) who were taking science courses (50%) or math courses (61%), compared to those seniors indicating a non-scientific career goal ( $N = 129$ ; 48% science, 58% math) or those who did not have a career goal ( $N = 33$ ; 52% science, 64% math).

Table 3 presents the components of the job descriptions written by students that were included in a minimum of 10% of the responses. Chemists were characterized

as working in factories making drugs and cosmetics. Biologists were seen as finding cures for and treating diseases and observing animals, particularly sea mammals. Psychologists were described entirely in terms of counseling.

Unlike the study by Meade and Metraux, only 20% of the students mentioned laboratory work for any of the science occupations, and less than 2% of the students mentioned danger. Less than 3% of the students mentioned the scientific method or experimentation. Only four responses mentioned teaching. Twenty percent of students indicated that they did not know what psychologists did, 24% did not know what chemists did, and 13% did not know what biologists did.

In general, these results indicate that students know very little about scientists. The perceptions of the students seem much more influenced by popular media accounts of scientists' careers (hence the emphasis on marine biology, industrial chemistry, and counseling psychology) than by a broader view of the professions. It is perhaps too much to ask of public school science educators to provide career information in addition to instruction; organizations such as the Virginia Academy of Science, colleges and universities, and research corporations, as well as individual scientists, could provide the necessary resources to give students more accurate information about scientific training and career options.

#### ACKNOWLEDGEMENTS

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#### LITERATURE CITED

- Ashton, B. G., and H. M. Meredith. 1969. The attitudes of sixth-formers to science and scientists. *School Science Review*, 51:174.
- Beardslee, D. C., and D. D. O'Dowd. 1961. The college student image of the scientist. *Science* 133:997-1001.
- Chambers, D. W. 1983. Stereotypic images of the scientist: The Draw-A-Scientists Test. *Science Education* 67:255-265.
- Educational Testing Service. 1988. The science report card: Elements of risk and recovery. Princeton, NJ.
- Hawkins, D. 1990. Defining and bridging the gap. In E. Duckworth, J. Easley, D. Hawkins, and A. Henriques (Eds). *Science education*. Hillsdale, NJ: Lawrence Erlbaum Associates. pp. 97-140.
- International Association for the Evaluation of Educational Achievement. 1988. Science achievement in 17 countries: A preliminary report. New York, NY: Teachers College. 143 pps.
- Lowery, L. F. 1967. An experimental investigation into the attitudes of fifth grade students toward science. *School Science and Mathematics* 67:569-569.
- Mead, M. and R. Metraux. 1957. The image of the scientist among high school students: A pilot study. *Science*, 126:384-390.
- National Science Foundation. 1983. *Educating Americans for the 21st century*. Washington, DC: Author.
- Yager, R. E. and J. E. Penick. 1984. What students say about science teaching and science teachers. *Science Education* 68:143-152.



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# On the Discovery of Wherry's Unpublished Manuscript *"Pogonia Affinis in Maryland and the District of Columbia"*

Robert A. S. Wright

Central Virginia Biological Research Consortium  
5204 Riverside Drive, Richmond, Virginia 23225

## ABSTRACT

The federally endangered small whorled pogonia, *Isotria medeoloides* (Pursh) Rafinesque (formerly *Pogonia affinis* Austin) has not been seen or collected in Maryland or the District of Columbia since 1930. Very little habitat or other data apart from anecdotal journal notes or herbarium specimen label information are known to exist. An unpublished typescript, authored by the late Edgar T. Wherry, has been located in the archives of the Seed Laboratory of the Virginia Department of Agriculture and Consumer Services in Richmond, Virginia. This typescript describes four stations for the small whorled pogonia near Washington, D.C. and gives information on habitat, ecology and population numbers.

## INTRODUCTION

Between 1925 and 1945, a small group of amateur botanists and naturalists from Richmond, Virginia made some remarkable floristic discoveries east of Richmond in New Kent and Gloucester counties. Numerous new populations of local native orchids were located and several discoveries representing major range extensions for *Malaxis spicata*, *Liparis loeselli*, *Hexalectris spicata*, *Ponthieva racemosa* and *Isotria medeoloides* (*Pogonia affinis*) were established.

Among these exceptional "orchid hounds" was Miss Jennie S. Jones, the long-time supervisor of the Virginia Department of Agriculture Seed Laboratory in Richmond (Smith, 1969). She was one of few Richmond-area contacts for regional botanists who wished to visit and photograph many of these Virginia orchids.

Her acquaintances included Frank Morris, a Canadian, and Edward Eames of Buffalo, New York. Frequent letters, post cards and telegrams between these two gentlemen and Miss Jones resulted in several of the fine black-and-white plates featured in their book, *Our Wild Orchids* (Morris and Eames, 1929) which was considered at that time to be the most authoritative work on the eastern orchids.

Much correspondence between the late Miss Jones and other eminent botanists of the day, including Frederick Coville, O. E. Jennings, B. L. Robinson, H. W. Denslow and Edgar T. Wherry has recently been located in inactive research files at the Seed Laboratory. Dr. Edgar Wherry, then employed by the Washington office of the United States Department of Agriculture's Crop Chemistry Laboratory, frequently corresponded with Miss Jones and visited her to discuss the new orchid stations for his orchid ecology experiments (Wherry, 1927, 1928; Harvill Stevens and Ware, 1977).

Dr. Wherry wrote Miss Jones when he learned she was preparing to submit an article to *Rhodora* detailing her brother Felix's discovery in April 1928 of the small

whorled pogonia in New Kent County, Virginia. In his letter of July 29, 1929, Wherry explained:

"...A year ago I prepared a brief note on its [small whorled pogonia] discovery at two localities north of Washington but decided not to publish this. Evidently it is not rare at all, but has been overlooked... As it includes exact dates and some descriptive information I am sending you a carbon copy and you may use anything it contains. It should be added, however, that two other localities near Washington have since been discovered..."

It seems that both Dr. Wherry and Miss Jones opined that the new distributional information regarding the small whorled pogonia was not worthy of publication. However, the discovery of additional stations of this orchid by Miss Jones, rather than strengthening Dr. Wherry's resolve not to publish, served instead to change his mind on the matter as is evident in the following, written to Miss Jones in January of 1930:

"...The Morris and Eames Orchid book has come out, with full descriptions of the trips down in your neighborhood for *Pogonia affinis*, *Malaxis spicata*, etc...I see that Morris refers to *Pogonia affinis* as very rare. And so it is from the Canadian or New England standpoint, but evidently not for the middle states. Dr. Dunn in writing me some time ago mentioned that you had been inclined not to finish up your article upon this orchid, because so many localities now seem to be known. I hope you will reconsider this and go ahead and send the article to *Rhodora*, because it ought to be made plain to botanists that New England isn't the whole of the United States and that the south has a few things to show the north. Far from the repeated discoveries making this plant unimportant I think the reverse is true. If you had but a single new locality to report, that would be but a small addition to our botanical knowledge; but when you can point to the now recognized existence of eight or ten new localities, your article will mean a complete revolution in current ideas about the orchid in question..."

#### WHERRY'S MANUSCRIPT

*"Pogonia affinis* in Maryland and the District of Columbia"

Because of the presumable rarity of the green five-leaved orchid, *Pogonia affinis* Austin, the discovery of a new station for it is generally regarded as worthy of special publication. That the plant is commoner than usually supposed however, is indicated by the data here placed on record.

On May 20, 1928, Dr. J. F. Schairer, a chemist in the Geophysical Laboratory of the Carnegie Institution of Washington, was looking for native orchids in woods well known to Washington botanists near North Chevy Chase, Maryland and found a colony of ten or more plants of a five-leaved orchid, just past their prime, but unmistakably representing this species.

On July 8, 1928, Dr. G. W. Morey of the same laboratory and his daughter Jane, were searching even better known woods near Pinehurst about a mile further southeast in the District of Columbia. Miss Morey discovered a group of at least three plants of the same orchid with well-developed seed pods.

A few weeks later a third occurrence was found by Mrs. T. M. Knappen a half mile south of the preceeding station. The following spring Mr. O. M. Freeman discovered still another, one-half mile southwest of Chevy Chase Lake. This makes four stations in as many square miles.

At the Maryland and D. C. stations the orchid occurs in typical oak-hickory-dogwood forests which are so characteristic of this part of the Piedmont. It is not especially associated with beech trees, as in some other places. It prefers situations where the undergrowth is sparse and where it receives considerable sun, at least during early spring. Its soil reaction is high subacid to low midacid, active acidities 50 to 150 with a pH range of 5.3 to 4.8.

When past blooming, it can be readily distinguished from its relative, the purple five-leaved orchid, *Pogonia verticillata* (Willdenow) Nuttall by the stem being green instead of purple and by the presence of two or three alternate blackish bracts toward the base of the stem. This year (1928) was a poor one for the purple species, which is common in the Washington area. A few plants came up but many did not flower and virtually none produced seed.

The green one blooms two or three weeks later and conditions appear to have been favorable for it, as practically every plant in both colonies bloomed and set seed and at least a third of them had two capsules per stalk. Two specimens have been deposited in the United States National Herbarium. The species had heretofore only been represented by a single fragment from New Jersey. It is proposed to keep close watch on the new colonies, and should they be threatened by real estate operations, further collections will be made.

#### DISCUSSION

The data accumulated by both Dr. Wherry and Miss Jones on the small whorled pogonia in Virginia and elsewhere was evidently never published, and a comprehensive review of the literature reveals only scant locality and habitat data for the Maryland and District of Columbia small whorled pogonia stations (McAtee, 1930; Reed, 1964; Broome et al., 1979, 1980; Mehrhoff, 1980; Reveal and Broome, 1981, 1982; Poulos, 1985). In none of the references consulted can detailed data discussed in Wherry's unpublished article be found.

More than six decades have passed since Wherry first recorded the data that appears in his manuscript. Since the small whorled pogonia has not been observed in Maryland or Washington since 1930 (Broome et al., 1980; Gene Cooley, personal correspondence), it is now appropriate that this historical information be published. Broome et al., (1980) recorded the small whorled pogonia as "apparently extirpated and removed by the expanding urban sprawl of the Washington, D. C. area". Moreover, recent field work in the suburbs of Washington reveals that all historical stations for the small whorled pogonia described in Wherry's manuscript have been developed and little suitable habitat even within Rock Creek Park remains (Kent Minichiello, personal correspondence). Only an exhaustive search in Rock Creek Park would conclusively demonstrate that the small whorled pogonia has been extirpated from the environs around the District of Columbia.

#### ACKNOWLEDGEMENTS

The author (R. A. S. Wright) acknowledges the gracious assistance of the Virginia Department of Agriculture and Consumer Services Seed Laboratory staff

members Harry Smith, Betty Burwell, and Stephen Binns, who kindly permitted and encouraged my file investigations. I am indebted to Gene Cooley of the Maryland Natural Heritage Program and Larry Morse at The Nature Conservancy for providing me with some helpful data, literature and species accounts of the small whorled pogonia in Maryland and the District of Columbia. I thank Tom Rawinski of the Virginia Division of Natural Heritage for some helpful unpublished literature and I am especially indebted to Kent Minichiello for sharing pertinent up-to-date field data. I sincerely appreciate the helpful critical remarks on the manuscript received from both Donna Ware at the College of William and Mary Herbarium and Tom Wieboldt at the Massey Herbarium, Virginia Polytechnic Institute and State University.

#### LITERATURE CITED

- Broome, C. R., J. L. Reveal, A. O. Tucker and N. H. Dill. 1979. Rare and Endangered Vascular Plants of Maryland. Unpublished report, United States Fish and Wildlife Service, Newton Corner, Massachusetts.
- Broome, C. R., J. L. Reveal, A. O. Tucker and N. H. Dill. 1980. Status Report on the Endangered and Threatened Vascular Plants of Maryland. Unpublished report, United States Fish and Wildlife Service, Newton Corner, Massachusetts.
- Harvill, A. M. Jr., C. E. Stevens and D. M. E. Ware. 1977. Atlas of the Virginia Flora, Part 1, Pteridophytes through Monocotyledons. Virginia Botanical Associates, Farmville, Virginia.
- McAtee, W. L. 1930. Seventh Supplement to the Flora of the District of Columbia and Vicinity. Proc. Biol. Soc. Wash. 43: 21-56.
- Mehrhoff, Loyall A. 1980. The Reproductive Biology of the Genus *Isotria* (Orchidaceae) and the Ecology of *Isotria medeoloides*. Unpublished Master's Thesis, University of North Carolina, Chapel Hill.
- Morris, Frank and Edward Eames. 1929. Our Wild Orchids. Charles Scribner's Sons, New York.
- Poulos, Peter G. 1985. Small Whorled Pogonia Recovery Plan. Unpublished report, Office of Endangered Species, Region Five, U. S. Fish and Wildlife Service.
- Reed, Clyde F. 1964. The Orchidaceae of Maryland, Delaware and the District of Columbia. Castanea 29(2): 77-109.
- Reveal, J. L. and C. R. Broome. 1981. Minor Nomenclature and Distribution Notes on Maryland Vascular Plants With Comments on the State's Proposed Endangered and Threatened Species. Castanea 46(1): 50-81.
- Reveal, J. L. and C. R. Broome. 1982. Comments on Maryland's Proposed Endangered and Threatened Vascular Plants. Castanea 47(2): 191-201.
- Smith, Harry L. 1969. Herbarium of the Virginia Department of Agriculture and Commerce. Jeffersonia 3(4): 19-20.
- Wherry, Edgar T. 1927. The Soil Reactions of Some Saprophytic Orchids. Journal Washington Academy Science 17(2): 35-38.
- Wherry, Edgar T. 1928. Northward Range-Extensions of Some Southern Orchids in Relation to Soil Reaction. Journal Washington Academy Science 18(8): 212-216.

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## PERCEPTIONS OF SCIENCE : CHANGES NEEDED

Alvin M. Pettus

Secondary Education, Library Science  
and Educational Leadership Department

James Madison University, Harrisonburg, VA 22807

### ABSTRACT

Current perceptions of science as a discipline discourage students from participating in the study of science. Changes are needed in the way science is presented in schools and by scientists to change the popular perception of science as a separate and unique area of study and to increase student enrollments in science courses. Science instruction must be adapted to enable learners to associate level of understanding of science with quality of life and potential for success. Science instructors must view science as a basic area of study for all students at all school levels and they must be willing to adapt their instructional procedures to reflect that view.

### INTRODUCTION

What accounts for the lack of interest in science among American students at a time when there is much publicity about the importance of science? The lack of interest is evidenced by low enrollments in elective science courses in public schools and by relatively low enrollments in science majors in colleges. The premise of this paper is that because of the manner in which science is presented, students develop perceptions which inhibit them from choosing to participate in science.

It has been evident for some time that many students begin to develop negative attitudes about science by middle or junior high school.(Yager, 1982). Some authors (DeRose, Lockard, and Paldy, 1979) have suggested that the causes of the negative attitudes were inappropriate instruction in the earlier grades and insufficient time and emphasis placed on participation in science learning activities. Raizen and Kaser (1989) indicated that teachers often spend so much time on the "so called" basics of reading, mathematics, and writing in elementary schools that science receives very little attention. They also stated that the lack of time devoted to science is compounded by the ineffective instructional approaches used by teachers of science. Fensham (1986/87) appeared to blame the condition on the nature and emphases of the science curriculum, especially the science curriculum programs that were developed and implemented during the 1960s and '70s. He associated the content and emphases or themes of the curriculums with "elite science" or being suited to only a small proportion of students.

### PERCEPTIONS OF SCIENCE AND SCIENTISTS

Much of the current problem in science education seems to stem from perceptions that science is unique and different from other meaningful and profitable endeavors and that those who pursue study in science have special aptitudes and in many ways are unique and different from other people. Scientists are often viewed by students, teachers, and other citizens as uniquely bright or smart and sometimes even strange. Those who are highly motivated to study science are sometimes seen as being antisocial types who would rather mix their chemicals and

derive their formulas than associate with "normal" people. In recognition of this perception, a 1990 issue of Newsweek carried a cover story about science titled "Not Just For Nerds." (Cowley et al., 1990).

Schibeci (1986) reviewed reports to ascertain the image of science and scientists in the popular culture, community attitudes toward science and scientists, and student perceptions of scientists. His report indicated that the portrayal of scientists in the popular media has been stereotyped and that the images the popular culture holds of scientists are based on the more outlandish characteristics or behaviors of the broad range of behaviors found among scientists. Scientists have typically been portrayed as white males in white coats who are "obsessive and socially maladjusted." (Schibeci, 1986). Not surprisingly then, was the finding that students of all ages generally hold stereotyped images of scientists, or at the very least, hold unfavorable or negative images of scientists. A study by Chambers (1983) indicated that the problem may be somewhat international in scope. His study included school children from Canada and Australia as well as from the United States and he concluded that the stereotypes appear early in school children and increase as students advance through the grades. Schibeci's (1986) report related that part of the problem may be due to a general bias against intellectuals. He stated that "We need to begin to examine this important area and to attempt to identify ways in which science in popular culture might influence the teaching and learning of science in our primary and secondary schools" and that we need to place school science in the "human context."

Over the years, teachers and professionals in science have done little to dispel the notion that participation in science is a unique endeavor. Many elementary school teachers tend to hold the same images of science and scientists as the popular culture. They do not like science, enroll in only the minimum number of science classes, and teach as little science as they can. Because these teachers often do not feel comfortable teaching science, when they do teach it, it is done as a series of facts without great interest or enthusiasm. Of course, many of these teachers do not have the experiences or background to do otherwise.

Based on my observations, teachers of required science courses in secondary schools continue to emphasize the facts and vocabulary of science over its utility and the common aspects it shares with other fields. Many of these teachers demand that students who have not yet been "turned on" to science do time-consuming science fair projects as course requirements. These experiences further alienate the students, especially if they see no relationship between the experiences and everyday life.

"With no taste for science developed in their early years, it should not be surprising that most high school students breathe a sigh of relief as they end their study of science in ninth or tenth grade in a required introductory biology course." (Fort, 1990). Unless the students plan to enter a traditionally science related occupation, they see no reason to enroll in additional science courses. John Bishop (1992) reported that only 20 percent of tenth graders saw a relationship between taking the type of science and mathematics courses usually offered in the last three years of high school and becoming qualified for their occupation of choice.

Teachers of elective science courses in high school often demand that students have several prerequisites in science and mathematics. They may also use guidance

counselor accomplices to require minimum grades in the prerequisites. Therefore, the teachers of upper-level science courses usually end up teaching relatively small classes containing the very brightest students, based on the criteria applied in schools. Darling-Hammond (1990) stated that one reason for the low student participation rate in certain advanced courses in American schools is that the schools have tended to ration curricula opportunities to a small number of students who are presumed to be headed for intellectual pursuits. This perpetuates the "science for the few unique and brightest" perception.

Scientists in higher education have not provided much help in changing the uniqueness myth either. Tobias (1990) indicated that some universities offer large class sections of introductory science courses which are designed to weed out all but the most competitive and persistent students. She speculated that faculty members adhere to the belief that "true science students will not need to be appealed or pandered to," but will persevere. She argued convincingly that the manner in which science professors provide instruction in colleges and universities tends to have an adverse affect on the number and types of students who continue their study and preparation in the sciences. Based on information collected from a group of college freshmen, Brush (1979) concluded that students may avoid enrolling in the physical sciences because their self-image is far different from their view of science and their perceptions of the professors who teach the science courses. He stated that, "if students can see little of the creativity of scientific inquiry and much of the mundane drudgery, then it seems reasonable that they would shy away from the field and people in it."

As a result of his research findings, Schibeci (1986) suggested that scientists themselves often cultivate the stereotypic images of science and the scientist. When scientists display their knowledge and ability by presenting demonstrations that impress their audiences as mystical and magical, the scientists may be confirming in these people the popular and undesirable perceptions of science and scientists.

#### CHANGES NEEDED

If the goal is to have a scientifically literate society, we must determine how to get the non-science oriented students and the non-scientist citizenry to develop some minimum level of knowledge and understanding of science and its implications. An important part of the process involves changing the popular perceptions that science is a difficult area of study which should be reserved for people with unique interests and aptitudes and that science is a discipline that has little practical relationship to other disciplines or to non-science careers. If people perceive science knowledge and understanding as being related to their quality of life, it is likely they will be motivated to participate in activities to learn science. Another part of the process is to present science learning activities so that the target audiences can readily understand them. This part of the process is particularly important if the objective is to increase the level of understanding among all learners rather than to select from among them those who already have high levels of knowledge and interests in science.

Elementary and middle school science teachers must be required to get enough science preparation to confidently provide appropriate science instruction for their students. In addition to making sure the teachers have an adequate amount of science preparation, emphasis must be placed on adapting the preparation to

enable them to effectively apply it in teaching situations. Most elementary school teachers perceive of themselves as non-scientists. Therefore, science instruction for these teachers must be designed to help them understand the links between science and other curricular and life activities and to help them be as comfortable teaching science as they tend to be while teaching other components of the curriculum.

At the secondary school level, there is a need to provide science instruction as an integral part of the basic curriculum for all students. Hurd (1991) indicated that the content of science curricula, as well as the perspective of science instruction, needs to change. He stated that science content needs to reflect human experience and show the connections between science and personal development and social concerns. The perspective needs to change from "a historical one to a focus on learning to learn." This involves emphasizing the knowledge and skills needed to keep learning and adapting throughout life rather than emphasizing current facts related to a specific area of science.

Science teachers, school counselors, and school administrators need to subscribe to the idea that science study is appropriate for all students during every year of school. Effort should be made by those who implement curriculum to make the science offerings appropriate and relevant for students of all ability and interest levels. All students should feel welcomed to elect to take science courses throughout their secondary school years, regardless of their scholastic ability and career aspirations.

Science teachers and scientists must pace their teaching activities and presentations to avoid causing confusion and developing negative attitudes about science among students and non-scientists. This may require taking the time to make sure the non-scientists understand the vocabulary to be used and have the prerequisite knowledge and skills needed. The Association for the Advancement of Science (1990) indicated that teachers and scientists who attempt to communicate with non-scientists must be selective in the use of specialized vocabulary and terms usually associated with specialized fields in science. When used, the specialized vocabulary should be placed in a context that is meaningful to the target audience.

Science educators and scientists must accept the responsibility of communicating with and informing average students and non-scientists about science and display patience, tolerance, and empathy during the process. Brush (1979) suggested that science instructors at the college level try establishing better rapport with students by demonstrating warmth, sensitivity, and a sense of humor and by emphasizing creativity, independence, and the worth of the individual. Science instructors need to rethink the often expressed objective to have students learn to think like scientists and consider how they, as science educators, can learn to think like non-scientists so they can adapt their instruction accordingly.

#### SUMMARY

There is evidence that the manner in which science is treated and presented by instructors, scientists and the media has contributed to the development of perceptions of science that are undesirable and, perhaps, detrimental to the realization of a scientifically literate society. To change those perceptions, changes must be made in the traditional approaches to presenting science, especially in schools. Science must be thought of and presented as an important and practical endeavor for all.

The connections between science and other disciplines and between understanding science and success in personal life and non-science occupations must become evident to motivate serious study of science by non-science oriented students. The connections should be made evident as science lessons are taught and through the manner in which the school curriculum is structured.

Science teachers and others who present learning activities in science need to adapt those activities to the learners. They must show patience and compassion for those who may not already have great interest in science study. They must make sure the learners have the requisite vocabulary, knowledge, and skills to understand the information and activities to be presented. While continuing to accommodate and challenge the few who show exceptional aptitude and interest in science, science educators must also make effort to get all students to view on-going science study as relevant, rewarding, and basic. If this is not done, science courses will continue to be obstacle courses for "weeding out" students who do not already have high levels of interests and knowledge in science rather than serve as avenues for effectively promoting scientific literacy.

#### LITERATURE CITED

- American Association for the Advancement of Science. 1990. *The Liberal Art of Science: Agenda for Action*. Washington, D.C.: AAAS. pp. vii-viii.
- Bishop, J. H. 1992. Why U.S. students need incentives to learn. *Educational Leadership*, 49(6):15-18.
- Brush, L. R. 1979. Avoidance of science and stereotypes of scientists. *Journal of Research in Science Teaching*, 16(3):237-241.
- Chambers, D. W. 1983. Stereotypic images of the scientist: the draw-a-scientist test. *Science Education*, 67(2):255-265.
- Cowley, G., K. Springen, T. Barrett, and M. Hager. 1990, April 6. Not just for nerds. *Newsweek*, pp. 52-54.
- Darling-Hammond, L. 1990. Achieving our goals: superficial or structural reforms? *Phi Delta Kappan*, 72(4):286-295.
- DeRose, J. V., J. D. Lockard, and L. G. Paldy. 1979. The teacher is the key: a report on three NSF studies. *Science and Children*, 16(7):35-41.
- Fensham, P. J. 1986/87. Science for all. *Educational Leadership*, 44(4):18-23.
- Fort, D. C. 1990. From gifts to talents in science. *Phi Delta Kappan*, 71(9):664-671.
- Hurd, P. D. 1991. Why we must transform science education. *Educational Leadership*, 49(2):33-35.
- Raizen, S. A. and J. S. Kaser. 1989. Assessing science learning in elementary school: why, what, and how?. *Phi Delta Kappan*, 70(9):718-722.
- Schibeci, R. A. 1986. Images of science and scientists and science education. *Science Education*, 70(2):139-149.
- Tobias, S. 1990. They're Not Dumb, They're Different: Stalking the Second Tier. (An occasional paper on neglected problems in science education.) Tucson, Arizona: Research Corporation. pp. 81-92.
- Yager, R. E. 1982. Is science a bunch of boring facts? *The Science Teacher*, 49(4):41-42.



## VIRGINIA ACADEMY OF SCIENCE Executive Committee Minutes

March 7, 1992

University of Richmond

Present: Gerald Taylor, Jr. (President), Richard Brandt (Immediate Past President), Michael Bass (Past-Past President), Golde Holtzman (President-Elect), Carolyn Conway (Secretary), Blanton Bruner (Executive Secretary-Treasurer), Dean Decker (Director VJAS), Jim Martin (Editor/Business Manager VJS), Ertle Thompson (Chair Search Committee for VJAS Director)

The meeting was called to order at 10:17 a.m. by President Gerald Taylor.

### Approval of Executive Committee Minutes.

The minutes of the Executive Committee Meeting of November 17, 1991, were approved as corrected, as moved by Dean Decker and seconded by Richard Brandt.

President's Report - Gerald Taylor. Dr. Taylor's report (attached), which he will be giving at the Council meeting, included the following information:

1. An update on the joint VJAS Director/Science Liaison at the Science Museum of Virginia. Betty Blatt invited some VAS officers/representatives to the Science Museum of Virginia reception for State Legislatures in January. At this reception these individuals talked with Delegate Earl Dickinson and Secretary Dyke. Delegate Dickinson subsequently introduced an amendment to the state budget to fund the joint VJAS Director/SMV Science Liaison position. As of today the status of the budget is still not certain. Dr. Blatt has indicated that the paid position is the preferred choice. Our future direction will depend on the state budget.

2. Dr. Stephen Wright, Professor of Geography at JMU, has been appointed as interim secretary and Council representative for the proposed Geography Section. To date five contributed papers have been received; there may also be several invited papers.

3. Dr. Taylor received a letter from Dr. William Quivers concerning the appointment of several students from Hampton University as associate members of VAS in 1942. This matter will be investigated by the Archives Committee.

4. A member of the Academy, Paul Osborne, has requested that VAS establish an emeritus category for retired members. Dr. Taylor will ask Council if VAS should consider this.

During Dr. Taylor's report there was discussion of the following related matters: offering an invitation to the new Director of the Science Museum of Virginia to attend the Annual Meeting (especially the VJAS' Awards Ceremony) and eliminating receipt of the journal (with the exception of the Proceedings issue) for student members.

### President Elect's Report - Golde Holtzman.

A draft of the program, for proofing, will be passed out this afternoon to Council representatives. A special session on the rabies field trials will be held jointly

between Biology, Environmental Sciences, and Microbiology. The geology section is having a symposium with invited speakers. The topics of special symposia and the names of invited speakers will be listed in table of contents. Dr. Holtzman indicated that as of today he had received nothing from 8 to 10 sections.

During Dr. Holtzman's report, there was considerable discussion about numerous issues/proverbial problems related to the Annual Meeting: program development, adhering to published deadlines, problems with non-participating sections, getting membership and registration materials to students who will be presenting papers at meeting.

Secretary's Report. No report.

Treasurer's Report. No report.

Immediate Past-President's Report - Richard Brandt.

Tom Haas from VCU has unofficially agreed to be Local Arrangements Chairman for the 1996 meeting. Dr. Brandt is working to obtain meeting sites for 1997 (hopefully VA Tech) and 1998 (hopefully George Mason). Sites for the 1993 through 1995 meetings have already been established: Old Dominion University (1993), James Madison University (1994), VMI and Washington & Lee (1995).

Executive Secretary-Treasurer - Blanton Bruner.

There was no official report. Mr. Bruner requested that he be sent any information that must be sent out to all members.

Virginia Junior Academy of Science Director's Report - Dean Decker.

1. Several years ago VJAS went through the appropriate procedure with the Department of Agriculture and Commerce to qualify for fund raising. This will come up for renewal in May. Dr. Decker recommended that this be renewed. Cost would be approximately \$100. All present were in agreement.

2. Recently Eddie Hoffer of Allied Chemical visited Dr. Decker and presented VJAS with a check for \$750.

3. A large number (1477) papers were submitted, the largest number to date. Plans are for there to be 36 sections for paper presentation at the meeting with up to 21 papers per section. Approximately 650 papers will be presented at this year's meeting.

4. A program to make name tags and labels will be purchased locally. Cost is approximately \$79.

5. Lisa Martin has indicated the need to obtain a postal meter and scale for VAS office. Dr. Decker presented information concerning costs (approximately \$36 per month excluding postage cost). Discussion followed. Such an expenditure was not looked at enthusiastically.

1992 Local Arrangement Committee Report - Dean Decker.

Drafts of some of the registration information and the Schedule of Events were distributed. With respect to the VAS registration form, everything is the same as last year except the cost for the picnic and banquet and the inclusion of a line item for insurance. Dr. Decker reviewed the Schedule of Events and other meeting

information with the Executive Committee. Considerable time was spent looking at this information and making the necessary corrections/changes.

Other Reports.

Ertle Thompson reported for the Search Committee: Interim Director of VJAS. An individual, Don Cottingham, has been identified to serve (on a volunteer basis) as Interim VJAS Director. Discussion related to various aspects of the VJAS Director position (some of which had been discussed earlier during President's Report) followed. At the end of the discussion, Dr. Thompson moved that the Report of the Search Committee be accepted. The motion passed unanimously.

Dean Decker pointed out the need for a FAX machine to facilitate communication between Mr. Cottingham and the VAS office at the University of Richmond. Jim Martin suggested that the FAX facilities at the Parham Road Campus of J. Sargeant Reynolds Community College be used temporarily.

Old Business. None.

New Business.

President Taylor indicated that he would probably call a special Executive Committee meeting between now and May, possibly in April.

The meeting was adjourned at 12:15 p.m.

Respectfully submitted by:  
Carolyn M. Conway, Secretary  
Virginia Academy of Science

SUMMARY OF MOTIONS

EXECUTIVE COMMITTEE MEETING, MARCH 7, 1992

1. That the report of the Search Committee: Interim Director of VJAS be accepted. Moved by Ertle Thompson for the Committee. Motion passed unanimously.

## VIRGINIA ACADEMY OF SCIENCE Council Meeting Minutes

March 7, 1992

University of Richmond

Present: Gerald Taylor, Jr. (President), Michael Bass (Past-Past President), Stewart Ware (Past-Past-Past President), Golde Holtzman (President-Elect), Carolyn Conway (Secretary, Chair Business and Policy Review Comm.), Blanton Bruner (Executive Secretary-Treasurer), Dean Decker (Director VJAS, Chair VJAS Comm., Chair 1992 LAC), Jim Martin (Editor/Business Manager VJS), James O'Brien (Editor Virginia Scientists, Chair Publications Comm., Co-chair Psychology), Ertle Thompson (AAAS Representative, Chair Search Committee for VJAS Director), Jim Murray (Co-chair Awards Comm.), Art Burke (Chair Finance Comm.), Hugo Seibel (Chair Membership Comm.), Rae Carpenter (Chair Trust Comm., Chair Futures Comm.), Don Mikulecky (Chair Science Education Comm.), Harold Bell (Director Visiting Scientist Program), Scott Newton (Councilor Agriculture, Forestry, & Aquaculture), Rosemary Barra (Councilor Biology), Rich Whittecar (Councilor Geology), Lisa Alty (Councilor Medical Sciences)

The meeting was called to order at 1:22 p.m. by President Gerald Taylor. Those present introduced themselves.

### Approval of Council Minutes of November 17, 1991

The minutes of the November 17 Council Meeting at the University of Virginia were approved as corrected, as moved by Michael Bass and seconded by Hugo Seibel.

### President's Report - Gerald Taylor.

Dr. Taylor's report (attached) included the following information:

1. An update on the joint VJAS Director/Science Liaison position at the Science Museum of Virginia. A number of VAS officers/representatives met with representatives of the State Legislature at the Science Museum in January. As a result of this meeting a budget amendment to fund this position was introduced by Delegate Earl Dickinson. As of today the status of the budget, and therefore this position, is not certain.

2. Dr. Stephen Wright, Professor of Geography at JMU, has been appointed as interim secretary and Council representative for the proposed Geography Section.

3. Dr. Taylor received a letter from Dr. William Quivers concerning the appointment of several students from Hampton University as associate members of VAS in 1942. This matter will be investigated by the Archives Committee.

4. A member of the Academy, Paul Osborne, has requested that VAS establish an emeritus category for retired members. This will be considered later.

5. As in the past, there is a need to continue to increase VAS membership.

### VAS-Future's Committee Report - Rae Carpenter.

Copies of the report from the Future's Committee (attached) were distributed. As charged, this committee has considered several options for a "permanent home"

for VAS; in addition they have identified a willing assistant for the Executive Secretary-Treasurer. In his report, Dr. Carpenter presented, with appropriate explanatory information, three committee recommendations.

1. With respect to moving VAS offices to the Science Museum of Virginia, this could take place at any time. The Committee recommended/moved, however, that the move to the SMV be delayed until the VJAS Director position is clarified but that the intent to centralize operations at SMV be reaffirmed whenever that becomes feasible. The motion passed unanimously.

2. With respect to an assistant for the Executive-Secretary Treasurer, the committee has identified an appropriate individual, Dr. Arthur Burke, who has agreed to serve as a volunteer "learning apprentice" for a year. Dr. Burke would then serve for three or more years as an "emergency stand-in" if needed. The Committee recommended/moved that the Executive Secretary-Treasurer position remain part-time and that Dr. Burke be named by Council to the volunteer status (i.e., assistant) leading to emergency back-up and that the duties of the EST remain as in the past. During the short discussion period that followed, Dr. Taylor indicated that the Executive Committee was in support of this recommendation/motion. The motion passed unanimously.

3. The Committee recommended that there be a redefinition or re-evaluation of the position of Executive Secretary-Treasurer, but that the redefinition be tabled until the VJAS Director position is clarified. Some possibilities given for further consideration were a full-time Executive Secretary-Treasurer or a combination of the position of Executive Secretary-Treasurer and VJAS Director. The motion to table passed unanimously.

The report of the Futures Committee was unanimously accepted by Council.

#### Search Committee (Interim Director of VJAS) Report - Ertle Thompson.

Copies of the report of the Search Committee (attached) were distributed. In anticipation that the status of the paid joint VJAS Director/Science Liaison position at the Science Museum of Virginia would not be clarified by this date, the Committee had worked to identify a volunteer to serve as Interim VJAS Director. Dr. Thompson indicated that this was not a good year for a search in the state because of financial conditions. No state college or university (contacted through potential candidates for the position) was willing to make a commitment of release time or space. The Committee recommended that Donald Cottingham, a retired chemistry teacher from the Tidewater area who has worked extensively with VJAS, be appointed as the new VJAS Director. The Committee also recommended that the details and conditions of the interim "director" status be worked out by the Executive Committee between now and the May meeting.

#### **OFFICER'S REPORTS**

##### President Elect - Golde Holtzman.

With respect to the 1992 meeting at UR, Dr. Holtzman reported that to date approximately one-half of the section secretaries have submitted their section's program. He also indicated that he should be informed of any invited speakers for the section meetings. He reminded the Council representatives that a list of room

needs should be sent by each section secretary to Dean Decker, Chairman of the Local Arrangements Committee. A draft of the program was distributed to Council representatives for review. President Taylor thanked Dr. Holtzman for his work on the 1992 meeting. Dr. Taylor also reminded Council that there is up to \$100 available from his discretionary fund which may be requested by the sections to cover meeting expenses (e.g., costs of mailings, honoraria for invited speakers).

Secretary. No report.

Treasurer. No report.

Executive Secretary-Treasurer - Blanton Bruner.

Mr. Bruner reported that the official audit for 1991 has been completed and copies of the audit report distributed. The second notice for unpaid dues has been sent out.

Immediate Past President. No report.

Past-Past President. No report.

Past-Past-Past President. No report.

### LOCAL ARRANGEMENTS COMMITTEES, DIRECTORS, AND REPRESENTATIVES REPORTS

1992 Local Arrangement Committee - Dean Decker.

1. The plans for the UR meeting are on schedule. The program is being prepared; speakers have been obtained; information on lodging, etc. is being prepared for distribution. Dr. Decker distributed imprinted notepads and pens which will be passed out to all participants at the meeting.

2. With respect to the costs for registering the meeting, \$1 per person will go towards insurance. The question was raised about absorbing this into other costs. Dr. Taylor pointed out that by keeping this as a separate line item it will be obvious what it is for. Dr. Taylor suggested that the Executive Committee consider maintaining this liability insurance for the entire year to cover officers and representatives while traveling to council meetings, etc.

3. Dr. Debra Elmegreen who had already accepted the invitation to give the 1st George Jeffers Lecture will also give the Negus Lecture to the Senior Academy. Dr. Arthur Burke moved, with Dean Decker seconding, that a plaque be presented to Dr. Elmegreen (a former VJAS President) at the Awards Banquet from both VJAS and VAS. The motion passed unanimously.

4. Dean is working on a generic guideline for Local Arrangements Committees for future meetings. This will include information about what should/must be done at various points during the year in preparation for the annual meeting in May. This information could also be distributed to individuals and institutions who have been

contacted about hosting a future meeting or those who have indicated an interest in hosting a future meeting.

Director of Virginia Junior Academy of Science - Dean Decker.

1. In past years there has been an emphasis on fund raising for the position of paid VJAS director; this activity has been reduced during the current year. Recently Dean was contacted by one of the CEO's whose company had been contacted during previous fund raising activities. At a meeting with this individual, Dean was presented with a check for \$750 for VJAS activities.

2. A large number (1477) of papers were submitted, the largest number to date. Plans are for there to be 36 sections for paper presentations at the meeting with up to 21 papers per section.

3. There will be at least three new awards this year - marine science, infectious diseases (microbiology), biophysics and health. The amount of the special awards is in range of \$250 - \$500. In this context Rae Carpenter indicated that some of the endowment funds are large enough now to increase the amount of the awards. Dean indicated that members of the VJAS Committee are examining the criteria and amount for the different awards.

Editor and Manager of VA Journal of Science - Jim Martin.

The journal is one issue behind. The last issue for 1991 is on its way to the Post Office. Papers for the first issue for 1992 (which should be out before the May meeting) are in the computer. Dr. Martin indicated that major considerations for the journal are time management and publication costs. More papers are being submitted.

In response to a question from Rae Carpenter, Dr. Martin indicated that the passing of Frank Flint and Jack Wise would be appropriately noted in a future issue of the journal.

Editor of VA Scientists - James O'Brien.

As instructed at the last Council meeting, the newsletter was sent to all State legislators, state offices, and Federal senators and Congressmen. Dr. O'Brien is seeking one or two associate editors to help with the newsletter and to serve as a backup if such a need arises. A new printer in the Tidewater area (Letton Gooch) has been obtained for the newsletter. This will be more convenient and less costly than sending the newsletter to Richmond for printing.

Director of Visiting Scientists Program - Harold Bell.

Dr. Bell distributed copies of his report (attached). He indicated that VAS may want to consider publishing the Visiting Scientists brochure every other year rather than annually. Much discussion followed concerning the actual use of this program and speakers.

AAAS Representative - Ertle Thompson.

The written report was included along with the previously distributed report of the Search Committee: Interim Director of VJAS. Dr. Thompson reported that the meeting in Chicago was an excellent one. The American Junior Academy of Science meeting was of high quality despite some physical problems related to

seating and audio-visual equipment. There were no major policy changes presented to the AAAS Council. The Executive Board announced that at next year's meeting in Boston there will be an increased emphasis on science, mathematics, and technology education in all section programs. Much concern was expressed at the meeting over the lack of funding of proposals for workshops for Academies of Science representatives and new Junior Academy directors.

Science Museum of Virginia Trustee. No report.

#### STANDING COMMITTEE REPORTS

Archives Committee. No report.

Awards Committee - Jim Murray.

After distribution of the Committee's report (attached), Dr. Murray moved on behalf of the committee that Dr. Richard Brandt be elected a Fellow of VAS. The motion passed unanimously. Dr. Murray indicated that the Committee will also be awarding an Ivey F. Lewis Distinguished Service Award at the Annual Meeting. Members of Council were asked to think of possible future Fellows. Nominations are to be made before October.

Dean Decker suggested that the Awards Committee be responsible for inviting family members of award recipients to the banquet.

Constitution and Bylaws Committee.

There was no official report. Mr. Bruner indicated that the paperwork to make the Committee on the Environment (ad hoc) a Standing Committee would be going out soon.

Finance and Endowment Committee - Art Burke.

Dr. Burke indicated that VAS Finances look good largely because of last year's meeting at VA Tech. He asked if VAS has an 800 telephone number. President Taylor asked Mr. Bruner to look into the possibility of obtaining an 800 number. President Taylor pointed out the future need to look at the accounting of VJAS funds.

Fund Raising Committee. No report.

Junior Academy of Science Committee. No report.

Long-Range Planning Committee. No report.

Membership Committee. No report.

Nominations and Elections Committee - Stewart Ware.

1. As required by the Constitution and By-Laws, Dr. Ware presented, for information only, the proposed slate of officers for 1992-93. The Committee considered two things in preparing this slate: those members who had been on ballots in previous years (but who had not been elected) and those newer members who have been involved in section activities. Dr. Ware noted that in contrast to

previous years (in which there were two nominees per office), this year (as a result of a change in the By-Laws) there is only one nominee per office. The slate is as follows:

President-Elect - James P. O'Brien (Tidewater Community College)

Secretary - Lisa T. Alty (Washington and Lee University)

Treasurer - Ralph P. Eckerlin (Northern Virginia Community College)

Dr. Ware reminded Council that according to the By-Laws, write-in nominees are still possible with the endorsement of 25 members.

2. In an effort to reduce the costs associated with mailing the notice of the proposed slate of officers and then later mailing a separate ballot, Dr. Ware, for the Committee, recommended/moved that the following wording be included with the slate sent out to members: Enclosed is a ballot listing nominees approved by the Nominations and Elections Committee for the three offices of the VAS that must be elected by the membership. Notice that since only one nominee is proposed for each office there is a provision for a write-in vote for each office. In accordance with the Constitution of the Academy, if 25 or more members write in the name of the same person for an office a run-off vote will be held between the Committee nominee and the person receiving the most write-in votes.

A very lengthy discussion of this recommendation/motion followed. During the discussion Mr. Bruner indicated that the elimination of a second mailing associated with the election of officers would save the Academy approximately \$500. Don Mikulecky and Golde Holtzman, through an amendment, proposed alternative wording. With the exception of one abstention, the vote was for approval of the amendment (i.e., alternative wording).

The question was then called on the amended motion which was as follows: Enclosed is the slate of nominees approved by the Nominations and Elections Committee. According to the Constitution and By-Laws, names may be added to the slate by 25 members petitioning the Committee on behalf of each name to be added. If such petitions are received, then a ballot will be prepared and mailed in accordance with the Constitution and ByLaws. If no such petitions are received by

(an appropriate date would be given) then this slate will be elected by acclamation. Voting was by a show of hands: 11 in favor, 1 against, 4 abstentions (including Dr. O'Brien). Motion carried.

At the completion of Dr. Ware's report, President Taylor requested that Mr. Bruner ask Dr. Frank Leftwich (Chair of Constitution and ByLaws Committee) to format an appropriate change in the ByLaws so that the presentation of the slate of officers and subsequent voting on the officers can be conducted in an efficient and cost-saving manner. The general sense of those present was that elections should not occur at the Academy Conference.

Publications Committee - James O'Brien.

This committee met during the morning session and agreed to trade software.

Research Committee. No report.

Science Advisory Committee. No report.

Science Education Committee- Don Mikulecky.

Although there was no official report, Dr. Mikulecky indicated that he hoped to convene the committee soon.

Trust Committee - Rae Carpenter.

Copies of the report (attached) were distributed and explanatory information was provided. Gifts have been received in the General Fund, Fellows Fund, and VJAS Endowment Fund. Total holdings as of December 31, 1991, were \$186,133.

Virginia Flora Committee - Stewart Ware for Donna Ware.

As indicated in the written report (attached) the Flora Committee met in Richmond in February.

**OTHER COMMITTEE REPORTS**

Committee on the Environment. No report.

Committee on Policies and Business Review. No report.

**SECTION REPORTS**

Aeronautical and Aerospace Section. No report.

Agriculture, Forestry & Aquaculture Section - Scott Newton.

Approximately 100 letters were mailed out, and a number of phone calls were made, concerning this year's meeting. Fourteen papers (6 in agriculture and 8 in aquaculture will be presented.

Archaeology Section. No report.

Astronomy, Mathematics & Physics Section. No report.

Biology Section. No report.

Biomedical & General Engineering Section. No report.

In reference to this section, President Taylor indicated that Council should look carefully at this section, since there has been no activity or participation at the past several Annual Meetings.

Botany Section. No report.

Chemistry Section. No report.

Computer Science Section - James O'Brien for Greg Cook.

Call for papers was not received. This has caused some difficulties for this newly established section.

Education Section. No report.

Environmental Sciences Section.

Although there was no official report, Michael Bass indicated that there will be a symposium at this year's meeting at which papers on the testing of the rabies vaccine on Paramore Island will be presented.

Materials Science Section. No report.Medical Sciences Section - Lisa Alty.

All the section officers will change this year but there is a nomination slate.

Microbiology and Molecular Biology Section. No report.Psychology Section - James O'Brien.

There are 14 new student members in this section. All are enrolled this semester in Dr. O'Brien's honors course in Research Methods in Behavioral Sciences. In addition, the Psychology Club from Tidewater Community College as a service project) is joining VAS as an institutional member.

Statistics Section - Golde Holtzman for Donald Ramirez.

Dr. Holtzman reported that this section will have an invited speaker from Duke University.

Geology - Rich Whittecar.

Dr. Whittecar expressed this section's concern for the reduction (due to state budgetary cuts) in the research activities of the State Geological Survey.

Geography (Proposed New Section). No report.

In conjunction with the Section reports President Taylor indicated that Council needs to encourage the various sections to elect officers that will take the time for, and accept the responsibilities associated with, their respective offices. This is especially important for Council representatives.

**OLD BUSINESS**

Although there was no official old business, Carolyn Conway (in reference to a discussion at a previous Council meeting) reported that she had verified that the telephone number of the VAS was indeed listed in the Richmond area telephone book in the business section.

**NEW BUSINESS**

As indicated earlier in his report, President Taylor received a request from Paul Osborne asking that the Academy establish an emeritus category of membership. Dr. Taylor asked if we should establish such a category and if so, what action should Council take. During discussion several comments and/or suggestion were made. A change in the ByLaws would be required. Exactly what constitutes emeritus category (e.g., retirement, moving out of the state) would have to be established.

Although the initial suggestion was to send this matter to the Constitution and ByLaws committee, all present eventually agreed that it should be sent to the Membership Committee. Jim Murray moved, with Arthur Burke seconding, that this matter be turned over to the Membership Committee. Dr. Taylor indicated that this committee should look into the matter and make a recommendation back to Council with the intent that Council looks favorably toward establishing an emeritus category. The motion passed unanimously.

Announcements.

Prior to adjournment President Taylor thanked Golde Holtzman and Dean Decker for their hard work in preparing for the 1992 Annual Meeting.

President Taylor adjourned the meeting at 4:09 p.m.

SUMMARY OF MOTIONS  
COUNCIL MEETING, MARCH 7, 1992

1. That the minutes of the November 17 meeting be approved as corrected. Moved by Michael Bass and seconded by Hugo Seibel. Motion passed unanimously.
2. That the move of the VAS offices to the Science Museum of Virginia be delayed until the VJAS Director position is clarified but that the intent to centralize operations at the Science Museum of Virginia be reaffirmed whenever that becomes feasible. Moved by Rae Carpenter for the Future's Committee. Motion passed unanimously.
3. That the Executive Secretary-Treasurer position remain part-time and that Dr. Arthur Burke be named by Council to volunteer status (i.e., assistant) leading to emergency back-up and that the duties of the EST remain as in the past. Moved by Rae Carpenter for the Future's Committee. Motion passed unanimously.
4. That there be a redefinition or re-evaluation of the position of Executive Secretary-Treasurer, but that this redefinition be tabled until the VJAS Director position is clarified. Moved by Rae Carpenter for the Future's Committee. Motion to table passed unanimously.
5. That a plaque be presented to Dr. Debra Elmegreen (Jeffers and Negus Lecturer) at the Awards Banquet. Moved by Arthur Burke and seconded by Dean Decker. Motion passed unanimously.
6. That Dr. Richard Brandt be elected a Fellow of VAS. Moved by Jim Murray for the Awards Committee. Motion passed unanimously.

7. That the following wording be included with the slate of officers sent out to members:

Enclosed is the slate of nominees approved by the Nominations and Elections Committee. According to the Constitution and By-Laws, names may be added to the slate by 25 members petitioning the Committee on behalf of each name to be added. If such petitions are received, then a ballot will be prepared and mailed in accordance with the Constitution and ByLaws. If no such petitions are received by \_\_\_\_\_ (an appropriate date would be given) then this slate will be elected by acclamation.

Moved by Stewart Ware for the Nominations and Elections Committee and amended by Don Mikulecky and Golde Holtzman. Motion carried with 11 in favor, 1 against, and 4 abstentions.

8. That the request to establish an emeritus category of membership be turned over to the Membership Committee. Moved by Jim Murray and seconded by Arthur Burke. Motion passed unanimously.

## Small Project Grants

The Research Committee of the Virginia Academy of Science has recommended funding or partial funding for the following small projects:

M. E. Arnegard and J. Cairns, Jr., University Center for Environ. & Hazardous Materials Studies, VPI & SU. Laboratory Investigation of a Proposed Field Method for Predicting the Effects Environmental Stressors on Algal Communities in Streams, \$523.00.

David R. Bevan, VPI & SU. Application of Symbolic Programming to Modeling of Protein Structure, \$750.00.

Ivor T. Knight, Dept. of Biology, James Madison University. Initial Investigation of the Use of Randomly Amplified Polymorphic DNA (RAPD) Markers for Genetic Analysis of the Four-Toed Salamander, \$970.00.

Frank Munley, Roanoke College. Study of Relaxation Effects in FeCO<sub>3</sub> Mossbauer Spectra, \$903.00.

Bruce Wiggins, James Madison University. Determination of Optimum Sampling Method of Bacteria in the Surface Microlayer of Freshwaters, \$938.00.

Michael H. Renfroe, Dept. of Biology, James Madison University, Biolistic Transformation of Pollen, \$1,000.00.

Lisa K. Muehlstein, Dept. of Biology, University of Richmond, Elucidation of the Host-Pathogen Interaction of Eelgrass Wasting Disease, \$458.00.

Maryanne C. Simurda, Washington & Lee University, Sequence Analysis of cDNA Clones of the Adult Worm *Schistosoma mansoni*, \$458.00.

## USGS NAMES NEW ASSISTANT CHIEF GEOLOGIST



Nancy Milton, an academy member and a resident of Washington, D. C., has been named Assistant Chief Geologist for the Eastern Region of the U.S. Geological Survey, Department of the Interior, in Reston, Va. In her new position, Milton promotes earth-science policies and programs, including energy research studies, mineral assessment activities, geohazard investigations, geologic mapping at many scales, and other research in onshore and offshore geologic framework and processes. She is responsible for the training, safety and health of scientific and technical staff east of the Mississippi River. As the representative for the Chief Geologist in the 26-state Eastern Region, she serves as liaison to geoscience agencies in the eastern United States.

Milton was born in Salem, Oregon. She attended the University of California at Berkeley, received her bachelor of science degree in botany from Howard University (1973) and her doctorate in plant ecology from Johns Hopkins University (1981). She first joined the USGS in 1975 and her USGS work at that time included conducting and supervising geobotanical research to develop remote-sensing techniques involving the spectral reflectance of plants. These techniques are used in geological applications such as assessing mineral resources, finding new ore deposits and identifying sites that have been contaminated by heavy metals.

From 1989 to March 1992, Milton was a budget examiner in the Division of Energy and Science, Office of Management and Budget, in Washington, D.C. She analyzed the Department of Energy budget components associated with high-energy physics and nuclear physics, fusion research, basic energy sciences, biological and environmental sciences and supporting research and technical analyses.

Milton belongs to many professional societies, including the American Association for the Advancement of Science, Botanical Society of Washington, Geological Society of Washington, Association for Women Geoscientists, Virginia Academy of Sciences and the American Society for Photogrammetry and Remote Sensing.

The USGS Geologic Division is responsible for assessing the nation's energy, land, and mineral resources and studying geologic features, processes and natural hazards through both field surveys and laboratory research.

## **NOTES**

## **NOTES**

## **NOTES**

# The James River Basin *Past, Present and Future*

COMPILED BY

THE JAMES RIVER PROJECT COMMITTEE

OF THE

VIRGINIA ACADEMY OF SCIENCE



A few copies of this classic (copyright, 1950), and possibly valuable, monograph are still available. 843 pages, 5 foldout maps

Contact the Journal Editor for information.

The volume represents the initial phase of research on the James River Basin. Emphasis was placed on what was known about existing conditions within the basin and what brought about the development of these conditions. An effort was made to show what was (in 1950) the present status of natural resources, agriculture, public health, education, transportation, industry, and recreational facilities within the territory drained by the James River. It attempts to present the past and present status of the James River Basin as a human habitat, and wherever possible, to indicate practical means for improving this human habitat.

The chapters in this book represent the interpretation by each author of the general objectives of the monograph on *The James River Basin-Past, Present, and Future* and the opinions expressed by them are not necessarily the official views of the Virginia Academy of Science.

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Three complete copies of each manuscript and figures are required. It is also suggested that authors include a 5.25 diskette in IBM compatible format containing a text file (ASCII) of the manuscript. Original figures need not be sent at this time. Authors should submit names of three potential reviewers. All manuscripts must be double-spaced. **Do not use special effects such as bold or large print.**

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### **EDITOR/BUSINESS MANAGER:**

**James H. Martin**  
Dept. of Biology - PRC  
J. Sargeant Reynolds Community College  
P.O. Box 85622  
Richmond, VA 23285-5622  
Phone: (804)371-3064

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## Spawning in *Semotilus corporalis* (Fallfish) (Pisces: Cyprinidae)

Eugene G. Maurakis and William S. Woolcott

Biology Department, University of Richmond, Virginia 23173

### ABSTRACT

Two reproductive behavioral characters of *Semotilus corporalis* (spawning clasp and spawning location on the upstream slope of the pit of a pit/ridge pebble nest) are consistent with those in other *Semotilus* species, supporting the monophyly of the genus. During the latter stages of nest construction, *S. corporalis* collects pebbles from the nearby substrate and deposits them on the pit/ridge nest to form a mound of pebbles, a behavior unique to the species.

### INTRODUCTION

There are conflicting reports regarding the spawning behavior of *S. corporalis* (fallfish). Ross and Reed (1978) stated that *S. corporalis*, unlike other *Semotilus* species, spawn communally over a nest. They were unable to identify isolated spawning between individual pairs of fish. Earlier, however, Greeley and Bishop (1933) indicated that female *S. corporalis*, held in a brief spawning clasp by a breeding male at the downstream end of the ridge of a pit/ridge pebble nest, were tossed upward with such force that their snouts often broke the surface with a splash. Raney (1969), apparently paraphrasing Greeley and Bishop, used a similar description of the spawning clasp and where in the water column it occurred in a popular account of the breeding behavior of *S. corporalis*. Maurakis et al. (1990), after finding that eggs of *S. corporalis* were concentrated in downstream pits of early-stage pit/ridge nests, hypothesized that, like other species of *Semotilus*, *S. corporalis* spawned in the pit as reported by Greeley and Bishop (1933). Here we present evidence from field observation and frame by frame analysis of video tapes that not only does *S. corporalis* spawn in the pit of a pit/ridge pebble nest, but has spawning techniques not unlike those of other *Semotilus* species.

### METHODS

Spawning was observed in Genito Creek (James River drainage), Co. Rt. 642, 2 km N of St. Rt. 6, 22 km W of Richmond, Goochland Co., Virginia, in waters of 16.2 C, 9 May 1991; and in Mill River (Connecticut River drainage), 1.6 km S of Amherst, Hampshire Co., Massachusetts, water temperature of 17.9 C, 15 May 1991.

Descriptions of nest-construction and associated behaviors are based on field observations, and video tapes recorded above the surface of the water with television cameras equipped with polarizing filters to minimize reflected light. Zoom macro lenses on cameras allowed the field of vision to be manually adjusted and focused for close-up and wide-angle views. Ten hours of videotapes, replayed frame by frame to identify spawning behaviors, were compared with field notes and literature accounts.

## RESULTS

A tuberculate, breeding *S. corporalis* (in full breeding color) constructed a well-defined pit/ridge pebble nest in less than 38 hrs in Genito Creek (no nest at 1830 hrs EDT, water temperature 14.2 C, 7 April 1991; nest present and active at 0815 hrs EDT, water temperature 16.2 C, 9 April 1991). An equal-sized tuberculate male (highly colored) and two tuberculate subordinate male *S. corporalis* (with subdued coloration) were also at the nest site. The nesting male excavated pebbles from the rear of the pit, and occasionally from the nearby streambed, depositing them on the upstream slope of the pit where eggs were later collected. During latter stages of nest construction, the nest-building male collected pebbles of sizes like those reported for the species by Maurakis et al. (1990) with his jaws primarily from the streambed and deposited them over the pit/ridge nest to form a mound of pebbles. This continued for two days until we stopped the activity and searched for eggs. Previously, we observed mound-building by *S. corporalis* males that continued for at least four days.

When a female moved into the spawning pit from a downstream position, the nesting male and sometimes a subordinate male aligned alongside the female. The trio, with the female between the males, moved forward to the upstream slope of the pit. Both males bent their caudal peduncles over the back of the female. The larger size, and resultant force, of the caudal peduncle of the nest-building male displaced that of the subordinate male from the back of the female. Then the larger male, with his pectoral fin under the breast of the female and his caudal peduncle over her back, forced her head up and tail down resulting in a spawning clasp. The clasp was like that observed in Mill River where a female was clasped by a single male *S. corporalis* at the upstream slope of the pit of a pit/ridge pebble nest. The male in this position encircled the vertically oriented female during the spawning clasp, similar to the clasps in *Semotilus atromaculatus* (Reighard, 1910); *S. atromaculatus*, *Semotilus lumbee*, and *Semotilus* sp. (Woolcott and Maurakis, 1988; Maurakis and Woolcott, 1990); and *Semotilus thoreauianus* (manuscript). The female, with mouth agape, was released from the clasp and drifted momentarily upside down before she regained equilibrium downstream of the pit.

## DISCUSSION

The male *S. corporalis* in the latter stages of nest construction, following spawning, collects pebbles from the nearby streambed and deposits them over the pit/ridge nest to form a mound of pebbles, a behavior unique to the species. This may enhance the survival of developing eggs in the interstices of a nest. During the mound-building period the male chases all fishes, including male and female *S. corporalis*, from the nest site. The aggressive behaviors minimize predation of the buried fertilized eggs during the period required for hatching. Laboratory reared eggs of *S. corporalis*, as well as those of other *Semotilus* species, did not hatch as yolk-sac larvae before seven days of development took place (pers. obs.). The yolk-sac larvae, negatively phototoxic, remained motionless during development, responding only to mechanical agitation by swimming until the stimulus was stopped. This suggests that yolk-sac larvae are procumbent while undergoing development in the interstices of a nest, unless disturbed. The swimming response of larvae may be a behavior that enhances their chances of survival as some

cyprinids and catostomids physically move pebbles in a nest as they forage for food. Also, changes in interstitial aeration may stimulate larvae to move to interstices farther upstream in the nest. We have collected large numbers of late-staged, yolk-sac larvae near the upstream base of mounds when nests were covered with silt.

Reed (1971) stated that fertilized eggs were always in a pocket within the nest and at a level of the original stream substrate. Like Reed, we collected the non-adhesive and non-cohesive fertilized eggs of *S. corporalis* in discrete areas, either on the upstream slope of the pit in a small pit/ridge nest or in the downstream base of a mature mound pebble nest (Maurakis et al., 1990).

Two reproductive characters of *S. corporalis*, spawning clasp and spawning location on the upstream slope of the pit where it joins the ridge, are behavioral synapomorphies that support the monophyly of the genus. The behaviors do not occur in the species of the other two pebble nest-building cyprinid genera, *Exoglossum* and *Nocomis* (Maurakis et al., 1991a; 1991b).

We agree with Greeley and Bishop (1933) and Raney (1969) regarding the spawning clasp and where it occurs in *S. corporalis*. Frame by frame analyses of the videotapes corroborate the descriptions of Atkins (cited in Kendall and Goldsboro, 1908) that ". . . by and by a female came swiftly along, and right over ed (ed in his diagram is identified as the crest of the upstream slope of the pit) was seen struggling in an erect position; the male was close to her, but nothing more could be made out." We interpret the description of the erect position of the female to correspond to the vertical position of the females that we saw during the spawning clasp.

Unlike Ross and Reed (1978), we have never seen nor filmed the communal spawning rush of *S. corporalis* over nests. We believe the "rush" is the forward swimming movement of the nesting male (and sometimes subordinate males) toward the female in the pit as she positions her self on the upstream portion of the spawning pit where she is subsequently clasped by the male.

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#### LITERATURE CITED

- Atkins, G. C. 1908. In: W. C. Kendall and E. L. Goldsboro. 1908. The fishes of the Connecticut lakes and neighboring waters, with notes on the plankton environment. U. S. Bur. Fish. Doc. 633.
- Greeley, J. R. and S. C. Bishop. 1933. Fishes of the upper Hudson watershed. In: A biological survey of the upper Hudson watershed. Suppl. 22nd Ann. Rept. N. Y. Conserv. Dept. 1932 (7):64-101.
- Maurakis, E. G. and W. S. Woolcott. 1990. Reproductive behavior of the creek chub, *Semotilus atromaculatus*. 70th Ann. Meet. Am. Soc. Ich. and Herp. Program Abstr.:125.
- Maurakis, E. G., W. S. Woolcott and J. T. Magee. 1990. Pebble-nests of four *Semotilus* species. Southeast. Fish. Council Proc. 22:7-13.

- Maurakis, E. G., W. S. Woolcott and M.H. Sabaj. 1991a. Reproductive behavior of *Exoglossum* species. Bull. Ala. Mus. Nat. Hist. 10:11-16.
- Maurakis, E. G., W. S. Woolcott and M. H. Sabaj. 1991b. Reproductive-behavioral phylogenetics of *Nocomis* species-groups. Am. Midl. Nat. 126:103-110.
- Reighard, J. E. 1910. Methods of studying the habits of fishes, with an account of the breeding habits of the horned dace. Bull. U. S. Bur. Fish. 28(1908):1113-1136.
- Raney, E. C. 1969. Minnows of New York, Part I: Facts about some of our chubs and dace. The Conservationist April-May, 1969:22-29.
- Reed, R. J. 1971. Biology of the fallfish, *Semotilus corporalis* (Pisces, Cyprinidae). Trans. Am. Fish. Soc. 199(4):717-725.
- Ross, M. R. and R. J. Reed. 1978. The reproductive behavior of the fallfish *Semotilus corporalis*. Copeia 2:215-221.
- Woolcott, W. S. and E. G. Maurakis. 1988. Pit-ridge nest construction and spawning behaviors of *Semotilus lumbee* and *Semotilus thoreauianus*. Southeast. Fish. Council Proc. (18):1-3.

## Comparison of Condition Index (K) of Spot (*Leiostomus xanthurus*) from the Elizabeth and York Rivers, Virginia<sup>1</sup>

Kinloch Nelson<sup>2</sup> and Herbert M. Austin

School of Marine Science, Virginia Institute of Marine Science  
College of William and Mary, Gloucester Point, VA 23062

### ABSTRACT

Condition Index (K) was measured on spot, *Leiostomus xanthurus* from the York (control) and Elizabeth rivers (Experimental-polluted) in 1983-1985. Condition indices for the two populations were regressed against seasonal temperature at the time of capture. Between 6.0 and 19.0 C the Condition Index of the two populations rises in synchrony. Above 19.0 C the Elizabeth River Condition Index continues to rise, and the York begins to drop. Above 26 C the York drops to levels approaching those of winter, and the Elizabeth continues to rise to the highest levels measured. It is hypothesized that this disparity is caused by high population densities of constantly recruiting juvenile polychaete worms in the Elizabeth sediments which are a major food source for the spot, and which provide sufficient nutrition to the fish to keep pace with high metabolic energy requirements. This large forage source, while supportive of high summer metabolism, is a potential pathway for enhanced sediment-fish pollutant transfer.

### INTRODUCTION

This study compares the Condition Index (K) of young-of-the-year spot (*Leiostomus xanthurus*) from the Elizabeth and York rivers, Virginia through several seasonal cycles between 1983 and 1985. Condition Index (K) is defined here as a coefficient that depicts the degree of "plumpness" or health of a fish (Moyle & Cech 1988). Young-of-the-year spot were chosen for three reasons: 1) retrospective data were available; 2) spot have been shown to be susceptible to Elizabeth River pollutants (Huggett et al, 1984; Hargis et al, 1984; Hargis and Colvocoresses, 1986; Hargis and Zwerner, 1988a; Plummer, 1988); 3) and young-of-the-year spot (75-135mm FL) have body proportions unaffected by allometric growth or spawning (Austin, unpublished data).

The Elizabeth River (Figure 1), which flows into the James River just west of Norfolk, Virginia is a sub-estuary of the Chesapeake Bay; and is reported to be the most polluted estuary in Virginia (Huggett et al, 1984; Hargis et al, 1984). Numerous military, industrial, and municipal outfalls are the main sources of the pollution. In one notable case, a fire in a creosote plant in the late 1940's resulted in the accidental discharge of large quantities of creosote which are still visibly detectable today. Polynuclear aromatic hydrocarbons (PAH's), one of the results of the fire,

1 Contribution No. 1761, Virginia Institute of Marine Science

2 Christopher's School, Richmond, VA and VIMS Virginia Governor's School, July, 1988

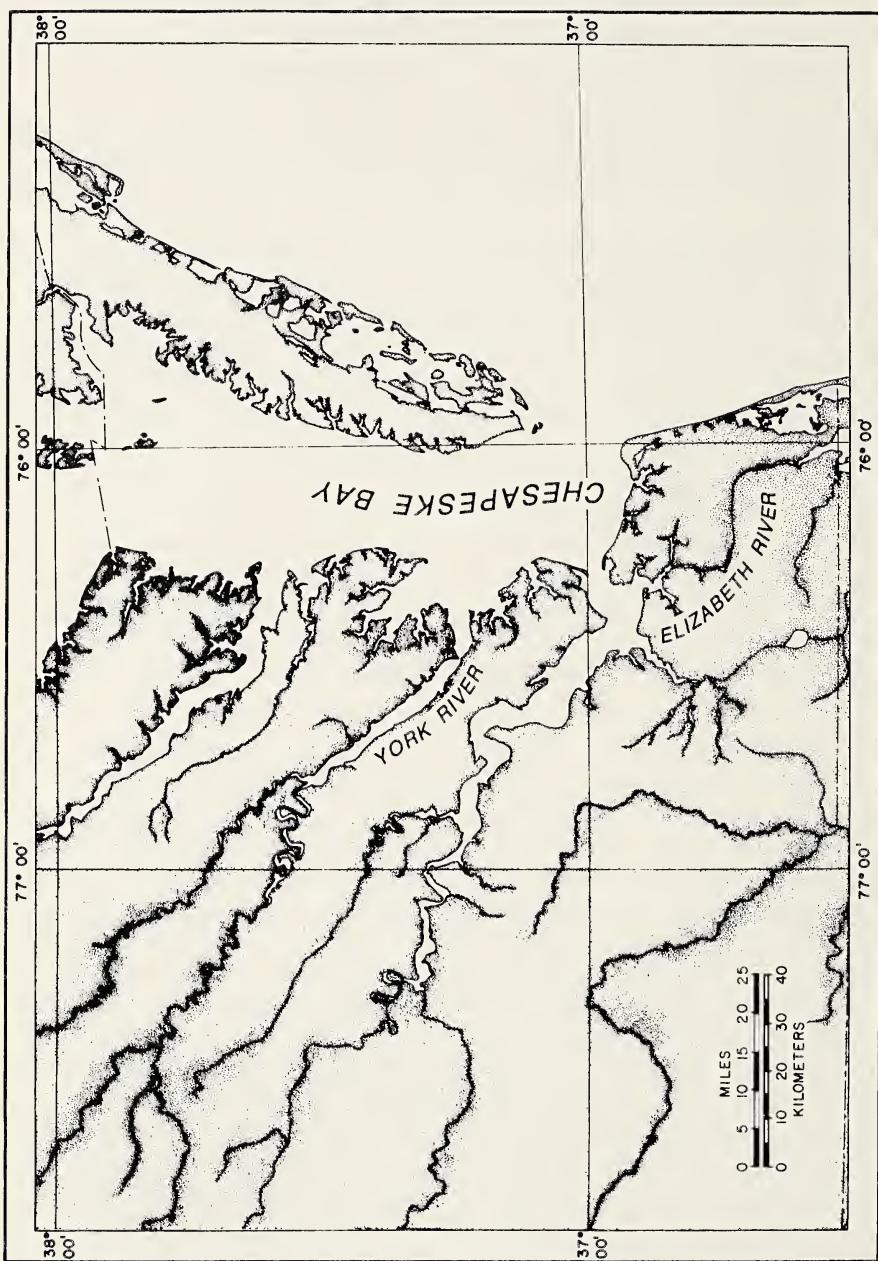


FIGURE 1. Map of tidewater Virginia showing the locations of the Elizabeth and York rivers.

and the creosote contamination that accompanied and preceded it; as well as activities at nearby petroleum transfer and storage facilities, continue at toxic levels in Elizabeth River sediments (Huggett et al, 1984). Young-of-the-year spot are normal year-round benthophagous residents of the Elizabeth.

The York River (Figure 1), on the other hand, located between the James and Rappahannock rivers is considered to be one of Virginia's "least" PAH-impacted riverine systems (Weeks et al, 1989). While the York is deeper than the Elizabeth, the gross physical-chemical environments of the two rivers are similar and one would expect fish populations to be similar. As such, one would also expect that the Condition Indices of spot would be similar in the two rivers sites. Conversely, considering the impacted Elizabeth sediments, and the benthophagous feeding habits of spot, one would expect the York River fish to be "healthier".

#### METHODS AND MATERIALS

Spot were taken using a 10 m semi-balloon otter trawl in both the York and Elizabeth rivers (Table 1). The sampling was conducted in connection with a bioassay project which was conducted from May to January during 1984, 1985, and 1986 (see for example, Hargis, et al 1984 and Hargis and Colvocoresses 1986). There were 32 cruises during this nine month period. All specimens were measured to the nearest 0.1 mm fork length (FL) with a measuring board, and weighted to the nearest 0.1g with a triple beam balance at sea. Generally, at least 16 samples per river were available for each cruise period.

Bottom temperature data were recorded to the nearest 0.1 C at each station at the time of collection. In a few instances however, temperature data were not measured. In these instances data were taken from the VIMS pier temperature records (York River kilometer 10) and extrapolated to the Elizabeth River since past VIMS investigators have shown there are direct liner relationships (Blaylock, 1984; Hsieh, 1979) in temperature between the VIMS pier and other Virginia estuaries.

Length and weight data were entered into the VIMS PRIME 990 and the Condition Index computed. Later, the indices and concurrent temperature data were loaded into a PC, and SAS graph was used to compute the regression coefficients and to plot Condition Index against temperature. The graphics software package plots a "best" fit to any X/Y data using a quadratic function and includes computations of r and p values when the graph is generated.

Condition Index was calculated based on the relation  $K = W/L^b$

where       $K$  = Condition Index

$W$  = Weight (g)

$L$  = Fork Length (mm)

$b$  is the slope of the regression line of  $W$  on  $L$  (Royce, 1972; Moyle and Cech, 1988). For spot,  $b$  was found to be 3.2.

The quadratic function was in the form

$$Y = a + bx + cx^2$$

TABLE 1. Condition Index, Temperature, and Date of Capture for Spot (*Leiostomus xanthurus*) collected from the Elizabeth and York rivers, Virginia; November, 1983 October, 1986.

River	Mean Condition Index (K)	Temperature (°C)	Date of Capture
York	4.55	8.5	23 Nov., 1983
York	4.55	8.5	2 Aug.
Elizabeth	4.68	8.0	8 Mar., 1984
Elizabeth	5.05	15.7	22 May
York	5.13	19.4	6 Jun.
Elizabeth	5.06	26.1	13 Jul.
Elizabeth	4.86	26.3	30 Jul.
Elizabeth	5.26	26.3	1 Aug.
Elizabeth	5.28	26.8	14 Aug.
Elizabeth	5.29	27.6	14 Aug.
Elizabeth	4.95	26.8	29 Aug.
York	4.46	27.1	29 Aug.
Elizabeth	5.38	22.4	18 Sept.
Elizabeth	5.34	22.4	18 Sept.
Elizabeth	5.28	22.4	18 Sept.
York	5.20	18.5	15 Oct.
York	4.96	18.5	15 Oct.
Elizabeth	4.20	16.2	7 Nov.
Elizabeth	4.40	14.5	12 Nov.
Elizabeth	4.69	8.5	16 Dec.
Elizabeth	4.75	21.8	16 May, 1985
York	4.31	21.5	20 Jun.
York	4.86	26.5	18 Jul.
York	4.50	27.0	24 Jul.
York	4.61	27.2	30 Jul.
Elizabeth	5.03	28.0	13 Aug.
York	4.87	22.9	28 Aug.
Elizabeth	4.81	18.9	22 Oct.
York	4.67	11.2	4 Dec.
York	4.56	11.2	4 Dec.
York	4.77	11.2	4 Dec.
Elizabeth	4.24	8.5	16 Dec.
Elizabeth	4.69	8.5	16 Dec.
Elizabeth	4.36	3.5	17 Jan., 1986
York	4.69	22.5	30 Sep.
York	5.18	17.9	7 Oct.
Elizabeth	4.93	17.9	7 Oct.
Elizabeth	4.73	17.9	8 Oct.

K values were computed for each fish, then averaged for all fish collected on each cruise. A typical sample was between six and 20 fish. Mean K values were regressed and plotted against water temperature for the date of capture.

### RESULTS

The maximum Condition Index for the York River was 5.2 reached at 18.5 C (Table 1). Minima were reached at 6.0 C (K=4.6), and again at 27.0 C (K=4.5). The maximum for the Elizabeth was 5.4 at 22.4 C, dropping slightly to 5.2 when 26-28.0 C. The seasonal minimum was 4.4 at 3.5 C.

The coefficients of determination ( $r^2$ ) for K regressed on temperature were 0.52 for Elizabeth River ( $p=0.0009$ ) and 0.42 for York River ( $p=0.0304$ ) (Table 2). Spot in the Elizabeth and York rivers have similar Condition Indices between 8.0 and 20.0 C (Figure 2). At 20.0 C the regression lines intersect. From 22.0 to 28.0 C, late summer, the York values drop to almost the same level or less than at 8.0-10.0 C (winter - early spring). Over the same temperature interval, the Elizabeth River index continues to increase; and above the 26.0-28.0 C mark the two rivers are separated by almost one half (4.5-5.0) Condition Index unit.

### DISCUSSION

Normally when compared to temperature, the Condition Index for poikilotherms shows the following seasonal pattern: fish are "thinnest" in cold temperatures, reach maximum "plumpness" at spring and fall temperatures, and during the hottest part of the summer drop down to almost as thin as they are in winter (Lagler, Bardach and Miller, 1962). Spot in the York River follow this normal pattern as evidenced by a low Condition Index in winter, rising in spring and early summer, and falling again during late summer (Figure 2).

The drop in K during the winter is normally due to the loss of food sources, reduced metabolism and physical activity. Fish achieve a balance between nutritional intake and metabolic rate during spring and fall. The subsequent summer drop in K is due to either one or a combination of factors: 1) available forage not providing sufficient nutrition to keep up with basal metabolic demands; 2) elevated ambient summer temperatures exacerbating environmental stresses; or 3) hypoxic or even anoxic conditions. Fish metabolism doubles with every 10 C increase in temperature (Lagler, Bardach, and Miller, 1962); consequently the metabolism of Chesapeake Bay spot is as much as four to six times higher in summer than in winter.

The Elizabeth River followed an atypical pattern for Condition Index versus temperature compared to the York River. Rather than getting thinner in the hottest months, Elizabeth River spot became more robust in summer than during either spring or fall. Considering that the metabolic rate doubles for every 10.0 C increase, and that the Condition Index for fish normally drops during the warmest months when metabolic requirements exceed food supply, leads us to speculate that the food supply for young-of-the-year spot in the Elizabeth must be unlimited and consistent through time. Juvenile polychaetes (Spionids, Nephthyids, and Maldinids), a primary food source for juvenile spot, are extremely abundant year-round in the Elizabeth River (Diaz and Schaffner, personal communication, VIMS) and recruit throughout the summer season. These polychaetes, in the absence of competition in the polluted sediments, have been found to produce

TABLE 2. Analysis of Variance and Quadratic Regression for Condition Index vs Temperature for the Elizabeth and York rivers, Virginia: November, 1983-October, 1986.

River	Sum of Squares	Mean Square	F value	R-square	Prob > F
Elizabeth	1.41278	0.70639	10.310	0.52	0.0009
York	0.45205	0.22602	4.623	0.42	0.0304

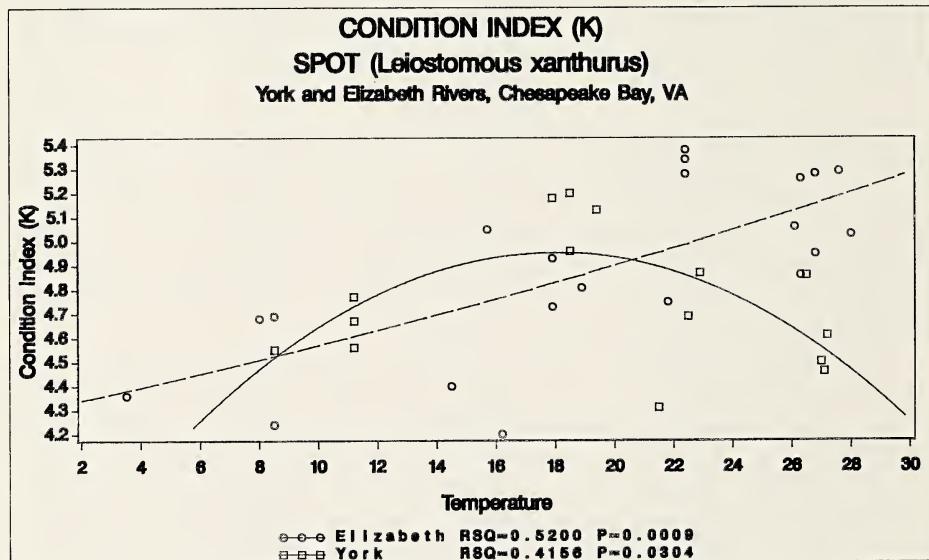


FIGURE 2. Temperature versus Condition Index (K) for spot, (*Leiostomusxanthurus*) Collected in the Elizabeth and York rivers, Virginia: November, 1983-October, 1986.

enormous populations which provide continuing abundant forage for the young-of-the-year spot even during "high metabolism" summer periods.

The unusually high Condition Indices for Elizabeth River spot during the warmer months suggest successful foraging. We speculate that the intimate contact between invertebrates and sediment, and the subsequent ingestion by spot could provide a rapid means of uptake of PAH's as well as other toxic material from the sediment. The higher Condition Index levels measured are probably a transient phenomenon since the subsequent incidence of cataracts, fin erosion, and lesions documented in the Elizabeth have been shown to produce chronic disease effects

(Hargis et al, 1984; Hargis and Colvocoresses, 1986; Hargis and Zwerner, 1988a and b, and Hargis and Zwerner, 1989).

#### CONCLUSIONS

1. The Condition Index versus temperature comparison of York River spot follows a normal, seasonal pattern.
2. The Condition Index versus temperature comparison of Elizabeth River spot follows a pattern of increasing Condition Index throughout the temperature range.
3. The increase in Condition Index in the Elizabeth River at high temperatures may be due to the unlimited availability of recently recruited benthic forage.
4. This rapid foraging, while supportive of high summer metabolism, is also a potential means of rapid sediment-fish pollutant transfer.

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We wish to acknowledge Dr's William J. Hargis, Jr. and J. Earnest Warinner, III, Virginia Institute of Marine Science (VIMS), School of Marine Science, College of William and Mary for the use of their unpublished length and weight data on spot. Comments by Dr's Robert J. Diaz, VIMS, and Hargis strengthened the paper, as did the comments by the anonymous journal reviewers. Mr. Robert Harris, VIMS provided the graphics. The initial impetus for this paper was a study initiated by Nelson as part of the VIMS-Virginia Governor's School Mentorship Program under the direction of Austin. The report was subsequently expanded upon by Austin, and prepared for publication.

#### LITERATURE CITED

- Blaylock, R. B. 1984. The Bottlenose dolphin in Virginia, MS Thesis, VIMS., Coll. of W&M, 56 pp.
- Hargis, W. J., Jr., M. H. Roberts and D. E. Zwerner, 1984. Effects of contaminated sediments and sediment-exposed effluent water on an estuarine fish: acute toxicity, Mar. Envir. Res., 14:337-354.
- Hargis, W. J., Jr., and J. A. Colvocorresses. 1986. EPA Workshop: Use of finfish as indicators of toxic contamination. Selected Gross Pathological Features. In Technical Resources, Inc. (Eds.). Proc. EPA Airlie House Workshop, July, 1986. Tech. Resources, Inc., 3202 Monroe St., Suite 300, Rockville, MD 20852, USA.
- Hargis W. J., Jr., and D. E. Zwerner, 1988a. Some histologic gill lesions of several estuarine finfishes related to exposure to contaminated sediments: A preliminary report. Understanding the Estuary: Advances in Chesapeake Bay Research. Proc. of a Conf. 29-31 March, 1988. CRC, 474-487 pp.
- , 1988b. Effects of certain contaminants on eyes of several estuarine fishes. Mar. Environ. Res. 24:265-270.
- , 1989. Some effects of sediment-borne contaminants on development and cytomorphology of teleost eye-lens epithelial cells and their derivatives. Mar. Environ. Res. 28:399-405.
- Hsieh, B. B. 1979. Variation and Prediction of Water Temperature in York River Estuary at Gloucester Pt., VA. MS Thesis, VIMS, Coll. W&M, 171 pp.

- Huggett, R. J., Bender, M. E., and Unger, M. A., 1984. Polynuclear Aromatic Hydrocarbons in the Elizabeth River, Virginia. Proc. Fate and Effects of Sediment-bound Chemicals, Colorado, 1984. pp. 327-341.
- Lagler, K. F., J. E. Bardach, and R. R. Miller, 1962. Ichthyology, Wiley and Sons, New York, 545 pages.
- Moyle, P. B., and J. J. Cech, 1988. Fishes: An Introduction to Ichthyology, Prentice-Hall, Inc., New York, 559 pages.
- Plummer, C., 1988. Some Graphic Effects of Water Pollution, Va. Mar. Res. Bull., 20(1): 1-21
- Royce, W. F., 1972. Introduction to the Fishery Sciences, Academic Press, New York, 351 pages.
- Weeks, B. A., J. E. Warinner, E. S. Mathews and A Wishkovsky, 1989. Effects of toxicants on certain functions of the lymphoreticular system of fish. Aquac. 6 pages.

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## Virginia's First Project 2061 Model Secondary Magnet School: An Example of Educational Reform<sup>1</sup>

Michael L. Bentley, Ed.D., Associate Professor  
Science Education, National-Louis University  
2840 Sheridan Road, Evanston, IL 60201

### ABSTRACT

To meet the educational needs of academically talented students and to supply the pool of scientists and engineers, secondary magnet schools for science and technology have proliferated throughout the country. The Southwestern Virginia Governor's School, one of the newest of these schools, has been influenced by *Science for All Americans* (1989), the Project 2061 study of the American Association for the Advancement of Science. This regional secondary magnet school was created in 1990 as a Project 2061 model to serve able students from eight rural Virginia school districts. The school's program and features were designed to be different from the four other regional magnet schools in the state. The Southwest Virginia Governor's School represents an example of a current reform effort in science education.

### INTRODUCTION

To meet the educational needs of academically talented students and to increase the pool of scientists and engineers, secondary magnet schools for science and technology have proliferated throughout the country. In 1990, a regional secondary magnet school was created in southwestern Virginia to serve able students in eight school districts. The School's curriculum was influenced by *Science for All Americans* (1989), the first phase of the American Association for the Advancement of Science's Project 2061<sup>2</sup>. Project 2061 (named for the next year Comet Halley will pass through the solar system) is AAAS's long-term, multiphase educational reform effort.

In this paper, the argument for creating specialized schools will be discussed, followed by a description of the planning and design of the program that was implemented in 1990. This program represents one interpretation of the Project 2061 model for reform in science education.

### RATIONALE FOR THE SPECIALIZED SCHOOL

Science, math and technology education have been the focus of some 300 reports about educational reform since 1983. The need for improving curriculum

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- 1 This paper is based upon a presentation made at the Annual Meeting of the Virginia Academy of Science, Blacksburg, VA, May 23, 1991. Dr. Bentley was the founding director of the Southwest Virginia Governor's School for Science, Mathematics and Technology. The address of the School is P. O. Box 1739, Dublin, VA 24084.
  - 2 There are four other science-math regional secondary magnet schools in Virginia. All were begun in the mid-eighties prior to the publication of *Science for All Americans*.

and instruction in these vital school subjects has been agreed upon by the communities of scientists and science educators, indeed, by almost all interested parties (National Science Board, 1983, I.A.E.E.A., 1988, A.A.A.S., 1989, Miller, 1988, Mullis and Jenkins, 1988, Stake and Easely, 1978, Weiss, 1987, 1978). The consensus appears to be that there is need for fundamental restructuring, both in content and teaching methods (Powledge, 1989).

The nation's leaders apparently connect our students' competence in science and mathematics to the country's global technological and economic leadership. There is concern that the pool of scientists and engineers needed to maintain U.S. competitiveness will not be adequate to the task. The National Science Foundation has projected a major shortage of scientific workers by 2006, with nearly 700,000 additional scientists and engineers needed. Currently, only about 5% of 22-year-old Americans earn B.S. degrees (Holden, 1989). Consequently, improving science and mathematics education is prominent among the six goals for public education announced by President Bush and the governors last year: "By the year 2000, U.S. students will be first in the world in mathematics and science achievement." (Rotberg, 1990)

It has become widely accepted in the U.S. that students who are academically able and motivated should be served by specialized programs which match their learning potential. The most able students represent the primary pool from which will come the country's next generation of scientists, engineers, and science and mathematics teachers. Specialized programs, often called "TAG" programs (for "talented and gifted"), have proliferated in school systems across the country in the past twenty years. TAG programs focus on one or more subject areas, and sometimes include advanced science and mathematics instruction for interested students.

More recently, regional specialized schools have been created to educate students of high ability who may not be appropriately served by local TAG programs. In some cases, local school systems may not have the resources to provide suitable science or mathematics experiences for capable students who are interested in more science and/or math.

Southwestern Virginia is an area where student achievement is below state and national norms on S.A.T. and other standardized tests, and where the average per pupil expenditure of \$3,362 is below the state median. Only 20% of the high school graduates go on to four year colleges (Department of Education, 1989). Moreover, of the top five percent of high school graduates who do enter college, 40% do not graduate. This has been attributed in part to the lack of academic challenge in most local secondary school programs (Virginia Association for the Education of the Gifted, 1990). In only a few of the rural school districts which comprise the consortium that created the new Governor's School have the ablest students had opportunities for even a limited amount of advanced coursework in science and mathematics.

#### PLANNING THE SCHOOL

A plan for a new regional magnet school for science, mathematics, and technology was developed in 1989-90 by a committee of school system personnel in the participating districts, comprising the cities of Galax and Radford, and Pulaski,

Montgomery, Giles, Floyd, Wythe, Bland, and Carroll counties<sup>3</sup>. The committee worked with the Department of Education and consulted with individuals associated with other magnet schools, particularly Lynchburg's Herb Vitale, who led the planning of the Central Virginia Governor's School in 1985.

The southwest magnet school project was funded by the Virginia Department of Education for the biennium, 1990-1992. The magnet school was designed to serve 110 high school juniors and seniors, beginning with a junior class. The school is governed by a Board comprised of one member from each of the school boards of the supporting districts. The superintendents of the districts take one year turns as "superintendent-in-charge."

Pulaski County Schools provided a facility for the school, a six classroom frame structure on the campus of Pulaski County High School in Dublin. The facility was built as a project by vocational students and previously was used primarily for computer instruction.

The new magnet school opened in August, 1990<sup>4</sup>. It offers a two year program in science, mathematics and technology for juniors and seniors. Students attend three hours each morning and return to local schools for other subjects and for extracurricular activities.

Each district provides funding for a number of "seats" at the magnet school. The selection of students is made by the local district, based upon their own criteria. Nominees are to be interested students capable of achievement in a rigorous science and mathematics program. For each year of successful participation, students receive three credits toward graduation: one each in science, mathematics, and research.

The first year, the staff consisted of two full-time teachers, who also administered the program, three part-time teachers, and one secretary. Additional full-time teachers were added the second year as the student body expanded.

In the summer of 1990 the building's physical environment was renovated to provide a variety of work and study spaces: laboratories, classrooms, seminar rooms, reading and AV rooms, and a computer center. The rooms were made stimulating and dramatic by wall-sized photomurals of science-related scenes.

#### THE CURRICULUM PLATFORM: PROJECT 2061

*Science for All Americans*, which was released by the American Association for the Advancement of Science in 1989, became the primary guide for the curriculum developed for the new school. In *Science for all Americans*, the AAAS calls for a restructured curriculum focused upon, "a common core of learning ... ideas and skills having the greatest scientific and educational significance for scientific literacy." (AAAS, 1989, p. 4) Several dimensions of scientific literacy are addressed, including key concepts and principles of science that all citizens need to understand. The scientifically literate person is defined as one who comprehends the

3 In the spring and summer of 1990, Grayson County joined the consortium project while Montgomery and Radford dropped out.

4 The School began with 43 juniors. Thirty-six completed the first year.

diversity and unity of the natural world. Such a person recognizes the interdependence of science, mathematics and technology, and the reality that these disciplines are human endeavors, which are subject to both strengths and limitations.

In *Science for all Americans*, scientific literacy is discussed in four general categories. The first category, the scientific endeavor, includes the development of science, technology, and mathematics from a historical point of view. Students can understand the development of science by studying the historical development of important concepts. The scientific endeavor also includes themes that pervade science, such as systems, models, constancy, patterns of change, evolution, and scale.

The second category, scientific views of the world, focuses on the beliefs and attitudes that have made the scientific endeavor so successful. Scientists hold that the world is understandable, that ideas are subject to change, and that while knowledge is durable, complete answers to all questions may not be possible through science. Scientists respect and demand evidence. They use logic and imagination to explain and predict. They try to identify and avoid bias, and reject authoritarianism. Scientists are guided by accepted ethical principles as they participate in the complex social activity of doing science.

The third category, perspectives on science, covers the basic knowledge about the overall structure of the universe and the physical principles upon which everything functions. Physical principles are organized into concepts on matter, energy, motion, and forces. Basic knowledge also includes how living things function and interact, which encompasses the diversity of life, the transfer of heritable characteristics, the structure and function of cells, the interdependence of all organisms and their environment, the flow of matter and energy in the biosphere, and evolution as the explanation for the similarity and diversity of life. The "big ideas" are stressed.

The final category, scientific habits of mind, is about scientific ways of thinking. The patterns of thought found in science are reflected in such specific skills as manipulation, observation, computation, and communication.

A fundamental premise of Project 2061 is that "less is more." The advice is not to teach more and more content, but to teach key concepts and principles, using improved teaching strategies. Other major premises relate to developing higher order thinking skills and teaching so that students see connections between disciplines.

### THE PROGRAM DESIGN

Following *Science for All Americans*, the content for the courses at the new magnet school center around "big ideas," hands-on experience, and problem solving, while optional offerings provide opportunities for students to investigate a variety of topics. Coursework emphasizes interpretive frameworks, major concepts, direct experience, communications skills, and cooperative group work.

In the two year sequence, the juniors undertake a group research project and a project involving the communication of science or math. The seniors, in turn, undertake in-depth studies in subdisciplines and individual and team projects.

Juniors take core science and mathematics courses and elect among laboratory courses in physics, chemistry and environmental science. The core course in

science, based upon Project 2061 recommendations, involves cross-disciplinary study with themes clustered into two major strands. One strand deals with structures and functions, scales, origins, and change in nature, while the second strand deals with science as an interpretive system and the relationship of science to technology and society. As recommended by Project 2061, the history and philosophy of science are woven into the course content.

The core math course focuses upon applied mathematics, emphasizing functional analysis and contextual pre-calculus, and leading to intuitive calculus. Students explore properties of mathematical relationships from an analytical as well as a geometric viewpoint. Topics recommended in Project 2061 are included, such as data collection and descriptive statistics, inferential statistics, mathematical modeling, and simulations.

Application work involves linear algebra, linear programming, operations research, probability, number theory, data analysis, discrete mathematics, and numerical methods. Additional facilitatory units are offered on computer usage, including word processing, data storage and retrieval, and science/math-related software.

Juniors elect one of three laboratory courses. The chemistry and physics courses include basic content at the introductory level, which involve extensive hands-on investigations. Students learn lab and safety skills and become familiar with tools used in these disciplines. Environmental science is broadly interdisciplinary and focuses upon field studies. A wooded area behind the school is used as the primary study site.

Student research is an important aspect of the program design. Research methods are taught through student participation in one of two interrelated group projects. Students work in task forces aided by an advisor. Students elect either to study the New River Valley watershed or to develop a model for efficient housing for the region. Both projects are vehicles for developing skill in research and communications, and both require integrating and applying knowledge across disciplines.

The program also provides students opportunities to pursue individual interests. Students are able to tap the resources and expertise of the community--its various industries, two community colleges and two state universities and the many retired professionals who live in the area. A variety of special interest offerings are structured in the following ways: as short-term seminars modelled on the Great Books program, as workshops (e.g. on computer languages and software), as skill-oriented tutorial sessions (e.g. on test-taking skills), as colloquia featuring guest speakers, and as Saturday and summer field trips. Offerings also are arranged in response to student requests and interests. Figure 1 illustrates the unique college-type "fortnight" schedule which provides the structure for the courses and the many elective opportunities.

The culmination of the junior year is a week long field trip to the Illinois Research and Development Corridor outside Chicago. Students visit modern research facilities at Fermilab, Argonne National Labs, Amoco Research Center, Chemical Waste Management Environmental Testing Laboratories, the University of Chicago, and Northwestern University. They meet and talk with scientists, mathematicians, and related professionals. They visit the Illinois Mathematics and

**Week I**

8:30 - 10:00 am	
M - W - F	LAB BLOCK (Physics, Chemistry, Env. Science)
T - Th	CORE BLOCK (Science, Math)
10:00 - 11:30	
M - W	OPTIONS (Seminars, Projects, Other studies)
T - Th - F	CORE BLOCK

SATURDAYS: Elective Field Trips (approx. alternate Saturdays)

**Week II**

8:30 - 10:00 am	
M - W	LAB BLOCK
T - Th - F	CORE BLOCK
10:00 - 11:30	
M	OPTIONS (Seminars, etc.)
T - Th	CORE BLOCK
F	COLLOQUIA (Guest presentations, interviews)
10:00 - 10:50	
W	OPTIONS (Seminars, etc.)
10:50 - 11:30	
W	COMMUNITY MEETING (or Options)

FIGURE 1. The "Fort-night" Schedule

Science Academy and some of Chicago's outstanding science and natural history museums.

One other significant feature of the program design is the student assessment system. While the school's students are selected because of demonstrated academic ability in math and science, nevertheless students are different in their starting points, interests and learning styles. Further, different paths ought to be available for students to reach particular academic goals and objectives.

In response to these realities, portfolios primarily are used to assess student progress. Students choose and place in a file the work that most represents their accomplishments. Students also have a voice in determining evaluation criteria. In addition to self-evaluations, students may include graded assignments, recommendations from instructors, records of work in teams and on independent studies, and excerpts from their "process logs" (journals).

Students work with an advisor through periodic meetings for goal setting and progress monitoring. Advisors coach their advisees in preparing the portfolios, which are reviewed by a staff committee each quarter.

### PROGRAM EVALUATION

An independent third party evaluation is desirable for a program where selected students benefit from public school funding significantly above the state per pupil average, such as in the case of the regional magnet school. An independent evaluation is desirable also for innovations which might be models for wider dissemination. Consequently, formative and summative evaluations were contracted to be done by a team headed by Dr. Robert Covert, Director, Evaluation Research Center, Curry School of Education, University of Virginia. This team designed an evaluation plan which addressed significant questions and accessed multiple sources of data (Shulha, 1991).

The Southwestern Virginia Governor's School has now completed its second year and the curriculum has, of course, evolved. An issue which divided the school community during its initial year was student assessment. The portfolio assessment model, which gives more responsibility to the student, is a radical change from traditional grading. Success in this model requires student planning and self-monitoring. The dispute over assessment resulted in changes in the school's program and in the staff.

The implementation of the model illustrates that, in education, results are sensitively dependent upon initial conditions<sup>5</sup>. The program for this school, as for others, is a product of negotiations between the staff, local district administrators, parents and students, and the school's governing board. Among these parties are a variety of educational values, expectations for the students, and perceptions of what are problems and what constitutes progress. Patience, persistence, open-mindedness, and realistic expectations are needed by all parties concerned with educational reform and with creating alternative schools.

This paper has been about a particular program modelled on AAAS's Project 2061. *Science for All Americans* is the current standard for designing such specialized programs, as it is for programs for all students. Meeting the specific needs of the ablest students is important, but should not be a substitute for reforming science and math programs for the majority of students. Specialized programs designed to improve science and mathematics education, such as this one, are warranted if fair, third party evaluations are conducted and if successful exportable features are disseminated throughout the educational community via teacher workshops, conference presentations, and publications.

Reform initiatives in the regular schools also should be supported by funding agencies, especially at the middle school level. The middle grades have been found to be most critical for the development of values, self-concept, and intellectual interests in young people (National Science Teachers Association, 1988).

Almost everybody agrees that improving science and mathematics education ultimately depends on helping teachers be more effective. Consequently, attention should be given to in-service teacher education programs and to on-going instruc-

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5 The "butterfly effect," a principle of chaos theory, is certainly as applicable to classrooms and schools as it is to phenomena in the physical realm.

tional support systems. Fortunately for Virginia, the Department of Education's V-QUEST initiative, currently funded by the National Science Foundation, should address needs such as these (Exline, 1990).

#### LITERATURE CITED

- American Association for the Advancement of Science. 1989. *Science for all Americans* (Project 2061). Washington, D.C.: Author. 217 p.
- Department of Education. 1989. *Facing up-23: Statistical data on Virginia's public schools*. Richmond, VA: Virginia Department of Education.
- Exline, J. 1990. *V-QUEST Report*. Unpublished report presented at the meeting of the Governor's School Directors, Richmond, VA.
- Holden, C. 1989. Wanted: 675,000 future scientists and engineers. *Science*, 244, 1536-1537.
- International Association for the Evaluation of Educational Achievement. (1988). *Science achievement in 17 countries: A preliminary report*. New York: Teachers College, Columbia University.
- Miller, J. D. 1988. "The roots of scientific literacy." In P.G. Heltne and L.A. Marquardt (Eds.), *Science learning in the informal setting*. Chicago: The Chicago Academy of Sciences. pp. 172-182.
- Mullis, I.V. and Jenkins, L.B. 1988. *The science report card: Elements of risk and recovery*. Princeton, N.J.: Educational Testing Service. 151 p.
- National Science Board Commission on Precollege Education in Mathematics, Science and Technology. 1983. *Educating Americans for the 21st century: A plan of action for improving mathematics, science, and technology education*. Washington, D.C.: National Science Foundation. 124 p.
- National Science Teachers Association. 1988. Science education for middle and junior high students. *American Middle School Education*. 7: 15-21.
- Powledge, T. M. 1989. What Shall We Do About Science Education? *The AAAS Observer* 5:1, 6-7.
- Rotberg, I.C. 1990. I never promised you first place. *Phi Delta Kappan*. 72: 296-303.
- Shulha, L. 1991. *The Southwest Virginia Governor's School*. Charlottesville: The University of Virginia Evaluation Research Center. 35 p.
- Stake, R.E. and Easley, Jr., J.A. 1978. *Case studies in science education*. Washington, D.C.: U.S. Government Printing Office. 170 p.
- Virginia Association for the Education of the Gifted. 1990. Sylvia Rimm Speaks on Underachievement. *Newsletter*. 13: 1.
- Weiss, I.R. 1978. Report of the 1977 national survey of science, mathematics, and social studies education. Washington, D.C.: U.S. Government Printing Office. 135 p.
- Weiss, I.R. 1987. Report of the 1985-86 national survey of science, mathematics, and social studies education. Research Triangle Park, NC: Research Triangle Institute. 146 p.

## Napoleon's Triangle

J. N. Boyd and P. N. Raychowdhury

Virginia Commonwealth University

Richmond, VA 23284

### ABSTRACT

Affine, convex coordinates were developed by the German mathematician A.F. Möbius (1790-1868). In this paper, we continue our work with convex coordinates and the Fermat point to show that Napoleon's (outer) triangle is equilateral.

### INTRODUCTION

There is a story that J. J. Sylvester was once shown a mathematical statement and asked whether he thought it was true or not. After he replied that there was no way for it to be true, he was shown a paper of many years before. In that paper, Sylvester himself had proved the statement to be true.

We compare ourselves with Sylvester in only one respect—his forgetting something he once understood. In a newsletter which we received not too long ago, the following elegant geometric fact was presented:

Suppose that, on the sides of any triangle ( $\Delta V_1 V_2 V_3$ ), equilateral triangles have been constructed so that the three equilateral triangles lie in the exterior of the original triangle. Then the triangle which has the centroids of the three equilateral triangles as its vertices is also equilateral.

### CONVEX COORDINATES AND NAPOLEON'S TRIANGLE

The geometry of the triangles is sketched in Figure 1 where  $Q_1, Q_2, Q_3$  are the centroids of the equilateral triangles upon the sides of  $\Delta V_1 V_2 V_3$ . The geometric fact, as we later learned, is quite well known with  $\Delta Q_1 Q_2 Q_3$  dignified by the Emperor Napoleon's own name (Coxeter and Greitzer). However, none of this information accompanied the bald statement which only had to do with the thirty degree angles at  $V_1, V_2$ , and  $V_3$ .

In Figure 1,  $\theta_i$  is the angle at  $V_i$ ,  $\ell_i$  is the length of the side opposite  $V_i$ ,  $P_i$  is the vertex of the equilateral triangle opposite  $V_i$ , and  $Q_i$  is the centroid of that equilateral triangle. When we first tried to prove this fact for ourselves, we did not see an obvious way to start. What we had forgotten was that the equilateral triangles are the same triangles needed for defining the Fermat point. (We thank Professor Ray Spaulding of Radford University for jogging our memory.)

We discussed the convex coordinates of the Fermat point of a triangle in this journal (Boyd, Lees, and Raychowdhury, 1990), and in this note we show how to use convex coordinates to prove that Napoleon's triangle is equilateral.

The Fermat point of  $\Delta V_1 V_2 V_3$  is the point at which the lines  $\overleftrightarrow{P_i V_i}$  are concurrent. We do not clutter our figure with these lines since they are not needed in the arguments to follow.

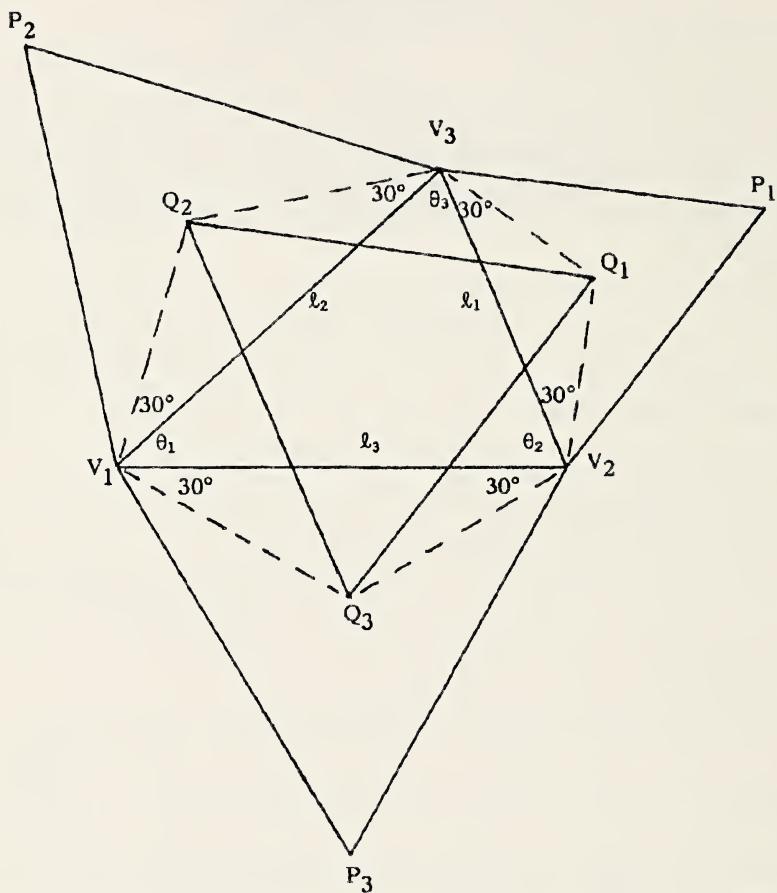


FIGURE 1. Napoleon's Triangle —  $\Delta Q_1Q_2Q_3$ .

However, in finding the convex coordinates of the Fermat point, we did find the convex coordinates of  $P_2$ , and we begin with that result. The convex coordinates of  $P_2$  are

$$(\alpha_{12}, \alpha_{22}, \alpha_{32}) = \left( \frac{\ell_1 \ell_2 \sqrt{3} \cos \theta_3 + 2A}{4A}, \frac{\ell_2^2 \sqrt{3}}{4A}, \frac{-\ell_3 \ell_2 \sqrt{3} \cos \theta_1 + 2A}{4A} \right)$$

where  $\alpha_{ij}$  is the convex coordinate of  $P_2$  with respect to  $V_i$  and  $A$  is the area of  $\Delta V_1 V_2 V_3$ .

The affine nature of convex coordinates forces a symmetry permitting us to write the convex coordinates of  $P_1$  and  $P_3$  as well. The convex coordinates of  $P_1$  are

$$(\alpha_{11}, \alpha_{21}, \alpha_{31}) = \left( \frac{-\ell_1^2 \sqrt{3}}{4A}, \frac{\ell_1 \ell_2 \sqrt{3} \cos \theta_3 + 2A}{4A}, \frac{\ell_1 \ell_3 \sqrt{3} \cos \theta_2 + 2A}{4A} \right)$$

and the convex coordinates of  $P_3$  are

$$(\alpha_{13}, \alpha_{23}, \alpha_{33}) = \left( \frac{\ell_1 \ell_3 \sqrt{3} \cos \theta_2 + 2A}{4A}, \frac{\ell_2 \ell_3 \sqrt{3} \cos \theta_1 + 2A}{4A}, \frac{-\ell_3^2 \sqrt{3}}{4A} \right)$$

Without loss of generality, we can take the Cartesian coordinates of  $V_1, V_2, V_3$  to be  $(0, 0), (1, 0), (a, b)$ , respectively, where  $a, b$  are both positive. Then the relations

$$\ell_1^2 = (1-a)^2 + b^2, \quad \ell_2^2 = a^2 + b^2, \quad \ell_3^2 = 1, \quad \ell_1 \ell_2 \cos \theta_3 = (\ell_1^2 + \ell_2^2 - \ell_3^2)/2,$$

$$\ell_2 \ell_3 \cos \theta_1 = (\ell_2^2 + \ell_3^2 - \ell_1^2)/2, \quad \ell_1 \ell_3 \cos \theta_2 = (\ell_1^2 + \ell_3^2 - \ell_2^2)/2$$

and  $A = b/2$  permit us to rewrite the convex coordinates in terms of just the two numbers  $a$  and  $b$ :

$$(\alpha_{11}, \alpha_{21}, \alpha_{31}) =$$

$$\left( \frac{-( (1-a)^2 + b^2) \sqrt{3}}{2b}, \frac{(a^2 + b^2 - a) \sqrt{3} + b}{2b}, \frac{(1-a) \sqrt{3} + b}{2b} \right),$$

$$(\alpha_{12}, \alpha_{22}, \alpha_{32}) = \left( \frac{(a^2 + b^2 - a) \sqrt{3} + b}{2b}, \frac{-(a^2 + b^2) \sqrt{3}}{2b}, \frac{a \sqrt{3} + b}{2b} \right),$$

$$(\alpha_{13}, \alpha_{23}, \alpha_{33}) = \left( \frac{(1-a) \sqrt{3} + b}{2b}, \frac{a \sqrt{3} + b}{2b}, \frac{-\sqrt{3}}{2b} \right).$$

Now  $Q_i$  is the centroid of its triangle. Therefore, its convex coordinates with respect to the vertices of the triangle for which it is the centroid are  $(\frac{1}{3}, \frac{1}{3}, \frac{1}{3})$ .

To obtain the convex coordinates of  $Q_i$  with respect to  $V_1, V_2, V_3$  we simply use the "chain rule" for convex coordinates (Boyd and Raychowdhury, 1989).

The convex coordinates with respect to  $V_1, V_2, V_3$  for  $Q_1$  are

$$\begin{pmatrix} \alpha'_{11} \\ \alpha'_{21} \\ \alpha'_{31} \end{pmatrix} = \begin{pmatrix} \alpha_{11} & 0 & 0 \\ \alpha_{21} & 1 & 0 \\ \alpha_{31} & 0 & 1 \end{pmatrix} \begin{pmatrix} \frac{1}{3} \\ \frac{1}{3} \\ \frac{1}{3} \end{pmatrix} = \begin{pmatrix} \frac{-((1-a)^2 + b^2) \sqrt{3}}{6b} \\ \frac{(a^2 + b^2 - a) \sqrt{3} + 3b}{6b} \\ \frac{(1-a) \sqrt{3} + 3b}{6b} \end{pmatrix}.$$

The convex coordinates with respect to  $V_1, V_2, V_3$  for  $Q_2$  are

$$\begin{pmatrix} \alpha'_{12} \\ \alpha'_{22} \\ \alpha'_{32} \end{pmatrix} = \begin{pmatrix} 1 & \alpha_{12} & 0 \\ 0 & \alpha_{22} & 0 \\ 0 & \alpha_{32} & 1 \end{pmatrix} \begin{pmatrix} \frac{1}{3} \\ \frac{1}{3} \\ \frac{1}{3} \end{pmatrix} = \begin{pmatrix} \frac{(a^2 + b^2 - a) \sqrt{3} + 3b}{6b} \\ \frac{-(a^2 + b^2) \sqrt{3}}{6b} \\ \frac{a \sqrt{3} + 3b}{6b} \end{pmatrix}.$$

The convex coordinates with respect to  $V_1, V_2, V_3$  for  $Q_3$  are

$$\begin{pmatrix} \alpha'_{13} \\ \alpha'_{23} \\ \alpha'_{33} \end{pmatrix} = \begin{pmatrix} 1 & 0 & \alpha_{13} \\ 0 & 1 & \alpha_{23} \\ 0 & 0 & \alpha_{33} \end{pmatrix} \begin{pmatrix} \frac{1}{3} \\ \frac{1}{3} \\ \frac{1}{3} \end{pmatrix} = \begin{pmatrix} \frac{(1-a) \sqrt{3} + 3b}{6b} \\ \frac{a \sqrt{3} + 3b}{6b} \\ \frac{-\sqrt{3}}{6b} \end{pmatrix}.$$

Since the Cartesian coordinates of  $Q_i$  are  $(0\alpha'_{1i} + \alpha'_{2i} + a\alpha'_{3i}, b\alpha'_{3i})$ , we can write the Cartesian coordinates of the vertices of  $\Delta Q_1 Q_2 Q_3$ :

$$Q_1: \left( \frac{3a + b\sqrt{3} + 3}{6}, \frac{(1-a)\sqrt{3} + 3b}{6} \right),$$

$$Q_2 : \left( \frac{3a - b\sqrt{3}}{6}, \frac{a\sqrt{3} + 3b}{6} \right), \text{ and}$$

$$Q_3 : \left( \frac{1}{2}, -\frac{\sqrt{3}}{6} \right).$$

Note that the Cartesian coordinates of  $Q_3$  are as expected. Finally, we compute the lengths of the sides of  $\Delta Q_1 Q_2 Q_3$  by the Pythagorean Theorem to find that

$$Q_1 Q_2 = Q_2 Q_3 = Q_3 Q_1 = \sqrt{\frac{a^2 + b^2 - a + b\sqrt{3} + 1}{3}}.$$

We have shown that Napoleon's triangle is equilateral by using convex coordinates and continuing the calculations begun in our discussion of the Fermat point.

#### LITERATURE CITED

- Boyd, J. N., Lees, J. J., and P. N. Raychowdhury. 1990. The Convex Coordinates of the Fermat Point. *Virginia Journal of Science* 41: 487-491.  
 Boyd, J. N., and P. N. Raychowdhury. 1989. A Chain Rule for Convex Coordinates. *Mathematics and Computer Education* 23: 30-34.  
 Coxeter, H. S. M. and S. L. Greitzer. 1967. *Geometry Revisited*. Random House, New York.



## Cryopreservation of Eukaryotic Algae

Myron H. Beaty and Bruce C. Parker, Biology Department

Virginia Polytechnic Institute and State University

Blacksburg, Virginia 24061

### ABSTRACT

Various cryoprotectants and cryopreservation techniques were applied to a wide selection of eukaryotic algal cultures. The most successful protocol involved algae cultured under low light ( $17-22 \mu\text{E m}^{-2} \text{ s}^{-1}$ ) on 1% agar media, controlled cooling at  $1\text{C min}^{-1}$  with 5% v/v Me<sub>2</sub>SO cryoprotectant, rapid thawing from -196C storage, and return to low light-1% agar media cultivation. This protocol allowed survival of 285 (78%) out of 365 algal strains tested. Moreover, 29 of the 57 genera were cryopreserved for the first time. Preliminary data suggest certain relationships among phylogenetic lines, habitats, cryoprotectants, and cryopreservability.

### INTRODUCTION

Cryopreservation of eukaryotic algae has been limited to relatively few taxa and has focussed mainly on damage sites induced by the freeze/thaw regime. Many of these studies aimed to understand freezing injury of higher plants or to store and maintain viable seed stocks (Gresshoff, 1977; Morris, 1981; Jordan et al., 1982; Styles et al., 1982; and Withers, 1987). Contrastingly, cryopreservation of algae as an alternative for maintaining algal cultures in a genetically stable state has not been a major goal. This goal has been all the more difficult, because poor understanding of the reactions between culture media, culture conditions, cryoprotectants, and organisms have kept cryopreservation studies of eukaryotic algae quite empirical.

Our objectives were to test a broader spectrum of algal taxa for cryopreservation; to investigate relationships between cryoprotectants, culture conditions, phylogenetic lineages, habitats, and cryopreservability; and to find a cryopreservation protocol offering a high degree of recovery.

### MATERIALS AND METHODS

#### Cultures and Culturing

We used 365 algal strains representing 13 algal classes obtained from various sources and grown in several culture media. Culturing was in liquid and/or on 1% agar media at 20C under cool white fluorescent light of  $17-22 \mu\text{E m}^{-2} \text{ s}^{-1}$ . Liquid cultures were grown to densities of ca.  $10^5$  cells  $\text{ml}^{-1}$  in 15 to 20 ml of media in tubes.

#### Cryoprotectants

Various concentrations of dimethylsulfoxide (Me<sub>2</sub>SO), methanol, glycerol, dimethylsulfonium propionate (DMSP), dimethylsulfide (Me<sub>2</sub>S), betaine, polyvinylpyrroliodone (PVP-40, average mol wt 40,000), trehalose, and the mixtures Me<sub>2</sub>SO + 0.1M trehalose and methanol + 0.1M trehalose were tested for their overall effectiveness on a select few algae. Cryoprotectants were added to 2 ml plastic Nalgene screwcap cryovials containing a cell suspension of ca.  $10^5$  cells  $\text{ml}^{-1}$ , final volume 1 ml. Cell suspensions were exposed to cryoprotectants < 45 min prior to initiation of freezing to ensure adequate penetration while minimizing toxic effects. An exception was the use of 0.1M trehalose as the sole cryoprotectant

which was exposed to cells 24 h prior to freezing, as shown necessary by Bhandal (1985).

### Freezing Cycle

A two-step cooling regime similar to that of McGrath (1979) was used throughout. After exposure to cryoprotectant, cryovials were placed in the freezing chamber of a Cryomed model 1010A programmable freezing controller. The chamber was cooled  $1\text{C min}^{-1}$  with rapid cooling ( $25\text{C min}^{-1}$ ) around the heat of fusion point to reduce the length of the heat of fusion plateau. Subsequently, the chamber was warmed at  $6\text{C min}^{-1}$  until sample and chamber temperatures were within  $6\text{C}$  of each other; then an immediate return to a cooling rate (chamber) of  $1\text{C min}^{-1}$  was initiated until the sample reached -40C. After 15 min at -40C, vials were plunged into liquid nitrogen (-196C).

### Thawing

After a minimum of 1 wk in liquid nitrogen, vials were removed and placed in a 40C circulating water bath until the last visible ice crystal had melted. Vials were then agitated to produce a homogenous cell suspension, 0.02 ml of which was placed on 3 replicate 60 X 15 mm Petri plates containing 15 ml of sterile 1% agar media and spread with a sterile glass rod. Dishes were sealed with Parafilm and incubated as above. A large body of data show that cryopreservation success is little influenced by cryostorage time from several days to several years for several different cell types (Matsuki et al., 1990; Morris, 1981; Schwartz et al., 1990; Simione et al., 1977; and Simon, 1972), and we have rechecked several of our replicate vials after 6-12 months with essentially the same results.

### Viability

All plates were checked for growth up to 25 days. Recovery rates were assessed by comparison of colony forming units (CFU) of freeze/thaw samples with similarly plated aliquots of the unfrozen cultures or to Coulter electronic particle counts of unfrozen cultures. Evaluation of viability was performed and scored as follows: NG for no growth, + for 1-100 CFU's, + + for 100-1000 CFU's, and + + + for >1000 CFU's. Accurate direct cell count studies proved the reliability of this scoring scale and showed that Coulter counting produced high estimates of viable cells. Successful recovery was defined as those cultures producing enough colonies to reclaim the culture (2% of the CFU's of control plates or > 0.2% of the Coulter electronic particle count due to its overestimation of viable cell counts).

## RESULTS

Our preliminary surveys with a smaller selection of algal cultures revealed that cells grown in low light (vs high) on agar media (vs liquid) with 5% Me<sub>2</sub>SO as cryoprotectant (vs other concentrations and other cryoprotectants) were cryopreserved more often than other combinations. The application of this more successful protocol to 365 strains is summarized in Table 1. The 365 strains comprised 68 genera, 33 not previously tested; 285 strains (78%) including 57 genera, of which 29 were heretofore untested, were recovered successfully. Comparison among algal classes which contained > 10 strains (Bacillariophyceae, Chlorophyceae, Eustigmatophyceae, Prasinophyceae, and Xanthophyceae) indicated only slight variations in successful recovery. However, within an algal class

TABLE 1. List of 68 algal genera examined in this study with respect to their cryopreservation success given in # of strains successfully recovered and unsuccessfully recovered.

Genera	No. of Strains Successfully Cryopreserved	No. of Strains Unsuccessfully Cryopreserved
<b>Bacillariophyceae</b>		
<i>Achnanthes</i> *	1	0
<i>Cylindrotheca</i> *	2	0
<i>Navicula</i> *	2	0
<i>Nitzschia</i>	0	1
<i>Phaeodactylum</i>	5	0
<i>Stauroneis</i> *	1	0
<b>Charophyceae</b>		
<i>Euastrum</i> *	0	1
<i>Mesotaenium</i>	0	1
<i>Zygnema</i> *	0	1
<b>Chlorophyceae</b>		
<i>Ankistrodesmus</i>	2	0
<i>Asterococcus</i> *	1	0
<i>Axilosphaera</i> *	1	0
<i>Borodinellopsis</i> *	1	0
<i>Bracteacoccus</i>	3	0
<i>Carteria</i> *	1	0
<i>Characium</i>	1	0
<i>Chlamydomonas</i>	52	39
<i>Chlorella</i>	20	1
<i>Chlorococcum</i>	2	0
<i>Coccomyxa</i>	13	1
<i>Dactylococcus</i>	1	0
<i>Dunaliella</i>	1	5
<i>Eudorina</i>	0	2
<i>Gloeocystis</i> *	0	1
<i>Gonium</i> *	0	2
<i>Haematococcus</i>	1	0
<i>Nannochloris</i>	1	2
<i>Neochloris</i> *	5	0
<i>Neosponggiococcum</i> *	2	0
<i>Oocystis</i>	1	0
<i>Palmella</i> *	1	0
<i>Pandorina</i> *	0	2
<i>Planophila</i> *	1	0
<i>Platymonas</i> *	2	0
<i>Pseudococcomyxa</i>	1	0
<i>Pseudotetracyctis</i> *	1	0
<i>Scenedesmus</i>	8	1
<i>Tetraclysis</i>	1	0
<i>Trebouxia</i>	1	0

*continued*

TABLE 1. *continued*

Genera	No. of Strains Successfully Cryopreserved	No. of Strains Unsuccessfully Cryopreserved
Cryptophyceae		
<i>Cryptomonas</i>	0	1
Cyanophyceae		
<i>Agmenellum</i> *	1	0
<i>Calothrix</i>	1	0
<i>Lyngbya</i>	0	1
<i>Nostoc</i>	1	0
Dinophyceae		
<i>Cryptocodinium</i>	1	0
Euglenophyceae		
<i>Euglena</i>	0	2
Eustigmatophyceae		
<i>Eustigmatos</i> *	2	0
<i>Mondus</i>	0	1
<i>Nannochloropsis</i>	6	2
<i>Pleurochloris</i>	1	0
<i>Vischeria</i>	4	0
Phaeophyceae		
<i>Ectocarpus</i> *	0	2
<i>Sphacelaria</i> *	0	1
Prasinophyceae		
<i>Prasinocladus</i> *	2	0
<i>Pyramimonas</i> *	1	0
<i>Tetraselmis</i> *	101	7
Prymnesiophyceae		
<i>Ochrosphaera</i> *	0	1
Rhodophyceae		
<i>Porphyridium</i>	3	0
Xanthophyceae		
<i>Botrydiopsis</i> *	3	0
<i>Botrydium</i>	2	0
<i>Bumilleria</i>	1	1
<i>Bumilleriopsis</i> *	1	0
<i>Chlorellidium</i> *	1	0
<i>Chloridella</i>	1	1
<i>Chlorocloster</i> *	7	0
<i>Heterococcus</i> *	4	0
<i>Heterothrix</i> *	4	0
<i>Nephrodiella</i>	1	0

\* indicates those genera which have not previously been examined

recovery rates varied markedly. The cryopreservation success rate for the algal orders tested within the Chlorophyceae is summarized in Table 2. The Chlorellales, Chlorococcales, and Chlorosarcinales which included many edaphic taxa showed much higher recovery rates than the Tetrasporales or Volvocales which included mainly aquatic taxa.

Percent recoveries of six algal taxa, representing xanthophycean and chlorophycean lineages (Dodge, 1979), frozen in optimal concentrations of 5 cryoprotectants are summarized in Table 3. The two lineages reacted differently to the various cryoprotectants. However, organisms within the same phylogenetic lineage exhibited similar responses to a given cryoprotectant. For example, the recovery rates of chlorophycean and prasinophycean algae decreased with increased concentrations of betaine, while recovery rates of bacillariophycean, eustigmatophycean, and xanthophycean algae were enhanced by increased concentrations of this compound.

#### DISCUSSION

Our studies, aimed at developing a better cryopreservation protocol applicable to a broader spectrum of eukaryotic algae, have continued with a largely empirical approach. However, an improved understanding and some intriguing ideas have emerged. Growth under relatively low light ( $17\text{-}22 \mu\text{E m}^{-2} \text{s}^{-1}$ ) and on agar media may have increased survivability by preconditioning the cells and reducing the amount of intracellular vacuolation, as suggested earlier by Morris (1981). Our recovery rates among algal classes showed only slight variations suggesting that taxonomic classes do not vary in the cryopreservability of their respective members; that is, class differences do not seem important to cryopreservation success. However, within the Chlorophyceae, the higher rates of success seen in the Chlorellales, Chlorococcales, and Chlorosarcinales as compared to the Tetrasporales and Volvocales suggest habitats may play a role in determining cryopreservability. The higher success rates of the first three orders above may be due to cytological or physiological mechanisms that counteract the hydration/dehydration and freeze/thaw cycles typical of many soil environments inhabited by many taxa from these groups (Round, 1981). Conversely, the more highly vacuolated Tetrasporales and Volvocales would not be expected to withstand desiccation- or freeze-induced stresses as well in their vegetative state. Their typical aquatic habitat lacks the desiccation and rapid temperature changes or freeze stresses of many soils. Therefore, development of desiccation- and freeze-resistant properties may be poorly developed in most of these aquatic species, except when they produce resting spores.

Recovery rates of several algae from two different phylogenetic lineages were compared (Table 3). The difference in reactions of these two taxonomic groupings to the various cryoprotectants and the similarity of reaction of the organisms within a given lineage may be attributable to conserved physiological characteristics along these phylogenetic lines. More research is needed for validation of such trends, which if confirmed, may allow selection of a cryoprotectant for a given organism and a better understanding of the cryoprotectant action.

This survey of 365 algal strains is the largest to date and encompasses more algal taxa than have been previously examined. The success rate of 78% recovery of all the algal strains tested rivals the success rates of the prokaryotes which includes

TABLE 2. Success rate of cryopreservation of orders within the algal class Chlorophyceae using 5% (v/v) dimethylsulfoxide as the cryoprotectant. % in ( ) indicate <10 strains tested.

Order	No. of Strains Successfully Cryopreserved	No. of Strains Unsuccessfully Cryopreserved	% Success
Chlorellales	39	4	90.7
Chlorococcales	21	1	95.5
Chlorosarcinales	5	0	(100.0)
Tetrasporales	2	1	(66.6)
Volvocales	58	50	53.7

TABLE 3. Percent recoveries based on CFU's and Coulter electronic particle counts of 6 algal taxa from two taxonomic lineages. % in ( ) are calculated from the electronic particle counts. NG denotes no growth.

TAXA	5% (v/v)	10% (v/v)	10% (v/v)	1% (w/v)	Betaine		
	Me <sub>2</sub> SO	Glycerol	Methanol	DMSP	1%	5%	10%
XANTHOPHYCEAN LINE							
Bacillariophyceae							
<i>Achnanthes brevipes</i>	(3.3) 18	(0.3) 26	(0.13) 13	(NG) NG	(0.2) 2.9	(1.9) 27	(1.4) 19.7
Eustigmatophyceae							
<i>Eustigmatos vischeri</i>	(11.2) 18.6	(39.4) 53.2	(9.9) 14.4	(1.3) 2.8	(2.1) 3.15	(4.1) 6.17	(29.5) 44.5
Xanthophyceae							
<i>Heterococcus fuornensis</i>	(53.9) 96.9	(24.4) 63.5	(14.8) 40.4	(1.2) 2.95	(29.9) 50	(50.8) 84.8	(55.9) 93.4
CHLOROPHYCEAN LINE							
Prasinophyceae							
<i>Tetraselmis sp. 87</i>	(1.6) 2.74	(2.7) 7.0	(0.3) 1.04	(NG) NG	(2.1) 7.5	(1.2) 4.2	(1.0) 3.6
Chlorophyceae							
<i>Chlamydomonas pseudococcum</i>	(18) 105	(23.6) 44.3	(38.7) 81.3	(13) 30.9	(27.7) 62.8	(19.6) 44.5	(19) 42.8
<i>Chlorella vulgaris</i>	(27.4) 112	(27.8) 31.7	(34.7) 54.3	(0.08) 0.14	(64.3) 147	(58.4) 134	(29.2) 67

the cyanobacteria (Albrecht et al., 1973; Heckly, 1978). This study shows that cryopreservation can be used as an alternative for maintaining cultures of eukaryotic algae and, in addition, for maintaining genetic stability and strain integrity. More studies are needed to determine the influence of habitats and phylogenetic lineages on algal cryopreservability, as well as to seek new cryoprotective compounds such as betaine.

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#### LITERATURE CITED

- Albrecht, R. M., G. R. Orndorff, and A. P. MacKenzie. 1973. Survival of certain microorganisms subjected to rapid and very rapid freezing on membrane filters. *Cryobiology* 10:233-239.
- Bhandal, I. S., R. M. Hauptman and J. M. Windholm. 1985. Trehalose as cryoprotectant for the freeze preservation of carrot and tobacco cells *Plant Physiol.* 78:430-432.
- Dodge, J. D. 1979. The phytoflagellates: fine structure and phylogeny, p. 7-57. In M. Levandowsky and S. H. Hunter (eds.). *Biochemistry and Physiology of Protozoa*. Academic Press, New York.
- Gresshoff, P. M. 1977. *Chlamydomonas rheinhardii*-model plant system-cryopreservation. *Pl. Sci. Let.* 9:23-25.
- Heckly, R. J. 1978. Preservation of microorganisms. *Adv. Appl. Microbiol.* 24:1-53.
- Jordan, J. L., L. S. Jordan and C. M. Jordan. 1982. Effects of freezing to -196°C and thawing on *Setaria lutescens* seeds. *Cryobiology*, 19:435-442.
- Matsuki, R., N. Liu and S. Sumida. 1990. Viability of marrow cells cryopreserved for 7 years at -196°C. *Cryobiology*, 27:627-628 (Abstract).
- McGrath, M. S. and P. M. Daggett. 1979. Cryopreservation of *Ochromonas* in liquid nitrogen with reproducibility of thiamin assay. *J. Protozool.* 26:230-231.
- Morris, G. J. 1981. *Cryopreservation*. Publication of the Institute of Terrestrial Ecology, Cambridge, England. 27p.
- Round, F. E. 1981. *The Ecology of Algae*. Cambridge University Press, New York. 653p.
- Schwartz, R. E., C. F. Hirsch, D. F. Sesin, J. E. Flor, M. Chartrain, R. E. Fromtling, G. H. Harris, M. J. Salvatore, J. M. Liesch and K. Yudin. 1990. Pharmaceuticals from cultured algae. *J. Indust. Micro.* 5:113-124.
- Simione, F. P. and P. M. Daggett. 1977. Recovery of a marine dinoflagellate following controlled and uncontrolled freezing. *Cryobiology* 14:362-366.
- Simon, E. M. 1972. Freezing and storage in liquid nitrogen of axenically and monoxenically cultivated *Tetrahymena pyriformis*. *Cryobiology* 9:75-81.

- Styles, E. D., J. M. Burgess, C. Mason and B. M. Huber. 1982. Storage of seed in liquid nitrogen. *Cryobiology* 19:195-199.
- Withers, L. A. 1987. The low-temperature preservation of plant cell, tissue, and organ cultures and seed for genetic conservation and improved agricultural practice, p. 389-409. *In* B. W. W. Grout and G. J. Morris (eds.). *The Effects of Low Temperatures on Biological Systems*. Edward Arnold Ltd., London.

**AWARDS ANNOUNCEMENT**

The following three Virginia Junior Academy of Science awards presented during the May, 1992 Academy meeting were not listed in the proceedings issue.

**COMMENDATION** of the intellectual property section of the Virginia State Bar to Dr. R. Dean Decker 21 May, 1992

We commend you for your many years of dedicated, volunteer service to the science-talented youth of Virginia. Your dedicated efforts have given incentive to the youth of our Commonwealth to focus upon their science talents, and, ultimately, better to contribute their own efforts to the well being of our Commonwealth and nation.

You have brought great credit to the Virginia Academy of Science, the Virginia Junior Academy of Science, and, your university. We, therefore, honor and salute you.

The intellectual Property Section of the Virginia State Bar

The Virginia Junior Academy of Science Distinguished Service Award on this date, May 21, 1991, is hereby presented to Lisa L. Martin and Lee Lawrence for outstanding contributions made to the Virginia Junior Academy of Science in its search for science aptitude among the youth of the State of Virginia and its efforts to develop scientists for the future.



Lisa L. Martin



Lee Lawrence

## NECROLOGY

Martha Lipscomb Walsh, 88, a distinguished high school teacher in Northern Virginia and Honorary Life Member of the Virginia Academy died October 18, 1992, after a long illness. After a long, productive and distinguished career, she will be greatly missed by students, friends and the Academy.

Martha grew up in Richmond and, in 1925, received her B.A. in Chemistry and English from Westhampton College, University of Richmond. She taught biology and chemistry at Thomas Jefferson High School in Richmond from 1930 to 1942. She received her M.A. in biology from the University of Virginia in 1940. She married in 1942 and returned to teaching in 1955 at McLean High School, Fairfax County, until her retirement in 1969. During these years she served as chair of the Science Department and was responsible for a large number of students becoming members of the Virginia Junior Academy of Science.

Martha received Distinguished Service Awards from the Virginia Junior Academy of Science, the Washington D. C. Academy of Sciences, and the Virginia Section of the American Chemical Society.

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Molecular Techniques for Population Genetics & Evolutionary Biology June 13 - July 2	Daniel Burke Assist. Prof. of Biology AND Michael Timko Assoc. Prof. of Biology		University of Virginia
Workshop in Allozyme Techniques July 4 - 17	Charles Werth Assist. Prof. of Biology		Texas Tech University
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July 18 - August 21			
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